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DISCOVERY AND EARLY HISTORY OF THE POSITIVE ELECTRON

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NEGATIVE electrons have been known by now for close on forty years. In this brief period they have been found in almost every situation and held accountable for almost all phenomena. It is a certain and familiar fact, attested daily by the working of countless millions of technical devices which depend upon it, that they can exist and travel freely in a rarefied gas or in a vacuum. Metals are believed to be full of freely wandering electrons, circulating past and even through the atoms. Negative electrons are thought to be responsible for almost every emission or absorption or scattering of light. They are a part of every atom-model and therefore one of the elements of every recent physical image of the world.

During all these years of the ubiquity of its negative counterpart, the *positive* electron has been "conspicuous by its absence." For twenty years at least it has been taken almost as a dogma that no such thing exists; it has been taken for granted that positive charge never appears in nature and must never appear in an atom-model, unless it is loaded down with a mass more than a thousand times as great as that of an electron. Two years ago the theorist Dirac was guided by theories of his own to conceive the positive electron, but no one had foreseen the way in which it was eventually found, and no one so far as I know was looking for it. It arrived as a by-product of the study of cosmic rays, thus adding one more instance to the list already long of great discoveries casually made during researches otherwise intended.

In the course of a big program of cosmic-ray research which Millikan had organized, C. D. Anderson was using the expansion-chamber or cloud-chamber of C. T. R. Wilson to observe the paths of ionizing particles belonging to these rays. Millikan and Anderson were not the first to do this. Others had already photographed the long straight tracks which these particles leave behind them (Skobelzyn's is the earliest name to be mentioned in this connection) and had furthermore observed that in a moderate magnetic field these tracks are either very slightly curved or not sensibly curved at all, so that the corpuscles which make them must be very fast. Anderson, however, made two important innovations.

Previously, everybody had set up the expansion-chamber with its axis vertical and its breadth horizontal, which is the most convenient way. Be it remembered that this chamber is a broad short cylinder filled with air or some other gas, its upper end closed by a transparent plate of glass, its lower end by a movable wall, which is the head of a piston. When the piston-head is suddenly pulled back through the proper distance (a matter of careful adjustment) and the gas expands to the proper degree, the moisture in the gas condenses upon whatever ions

there are; and in ideal conditions each droplet of water is the investiture of some ionized atom or molecule, and every ion is clothed in a visible particle of mist. Long lines of these visible particles mark out the paths of all the ionizing particles which have traversed the chamber shortly before the expansion. Now in the commoner kinds of experiment with Wilson's chamber, the ionizing particles proceed from some sort of laboratory source, a piece of radium, for instance, which can easily be set in the same horizontal plane as the rest of the apparatus; and then it is convenient to have the axis of the chamber vertical (Fig. 1), for the rays traverse the entire width of the gas beneath the cover-plate glass. But the ionizing particles of the cosmic rays mostly move in directions close to the vertical, and evidently the traditional orientation is a very poor one for observing these Anderson accordingly turned the whole apparatus on its side, so that the breadth of the chamber should lie in a vertical plane, and this is now the universal practise in cosmic-ray research. Such was the first of Anderson's innovations, but the second and greater one consisted in fitting into the chamber a leaden plate, of a thickness of several millimeters

Many of the ionizing particles of the cosmic rays have so great a momentum that they are able to pierce through even such a barrier with no measurable deflection (Fig. 2). Often indeed they are moving so tremendously fast that even in a strong magnetic field their tracks seem perfectly straight on both sides of such a plate [1] Anderson, however, had a magnetic field exceptional both for strength and for extensiveness, and a chamber of corresponding breadth (the field, of course, is parallel to the axis and perpendicular to the cover-plate of the chamber); and now and then he observed a track which traversed the plate and was more strongly curved on one side thereof than on the other (Fig. 3)

Consider any such a track The corpuscle which made it must have been

[1] A magnetic field bends the path of a charged particle moving, or having a component of motion, perpendicular to its own direction; the faster the particle, the less the curvature The undeflected particles of Fig 2 and similar pictures might conceivably have been uncharged, but from all we know it is extremely unlikely that an uncharged particle would ionize sufficiently many atoms of the gas to make so conspicuous a track

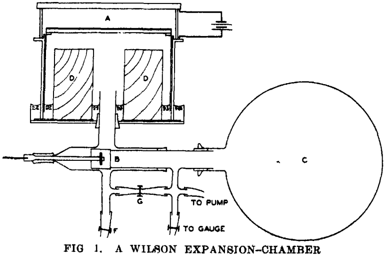

FIG 1. A WILSON EXPANSION-CHAMBER
(FROM C T R. WILSON'S ORIGINAL SKETCH. WHEN THE VALVE B IS OPENED THE AIR BENEATH THE GLASS PLATE UNDER A RUSHES INTO THE EVACUATED BULB C, AND THE PLATE DROPS ONTO THE BLOCKS D, INCREASING THE VOLUME OF A).

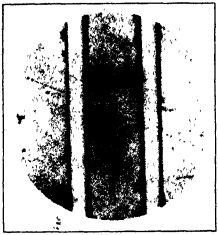

FIG. 2 TRACK OF A COSMIC RAY PARTICLE TRAVERSING TWO LEADEN PLATES EACH 6 MM THICK. (ANDERSON.)

going from the side where the curvature is less and the speed consequently greater, to the side where the curvature is greater and the speed consequently less. Otherwise we should have to assume that the corpuscle had picked up energy—a great deal of energy, tens of millions of electron-volts, indeed—in passing through the lead; and this seems inadmissible. Such a picture therefore fixes the sense in which the corpuscle described the track, and this fixing of the sense is not a trivial matter at all, but of the utmost importance, for with it the observer can tell from the picture (and from his knowledge of the magnetic field) whether the corpuscle was positive or negative, and without it he can not.

On the second of August, 1932, Anderson had a great piece of luck: he operated his expansion-chamber at just the right moment after the passage of a particle, which by this test was proved to be positive. A Wilson chamber, one must always remember, is not continuously at work; quite the contrary: it detects such particles as pass during the one or two hundredths of a second just before an expansion, and then a period of minutes, or at best a large fraction of one minute, must elapse before it can resume. In the course of a year of almost incessant work, Anderson had actually been observing less than half an hour altogether! A Wilson chamber in cosmic-ray research is more like a gambling device than anything else in physics; you wager the value of a photographic plate on each expansion, and nineteen times out of twenty or thereabouts you draw an absolute blank; but on this August day of 1932 Anderson drew the big prize.

He observed, as I said, the track of a particle which was proved to be positive; but this by itself is no sensational statement; there are various familiar kinds of positive corpuscles of much greater mass than electrons—alpha-particles and protons especially—and one must first of all inquire whether Anderson's particle could have been one of these. All these, however, are ruled out by the length and the appearance of the track. First, as to the appearance. As every one knows who has studied cloud-chamber pictures, the tracks of massive particles such as alpha-particles and protons are always much fatter and thicker than those of fast electrons. The massive particles produce many more ions per unit length of path, and therefore many more droplets of condensed water, than do the electrons. The difference is very striking to the eye;

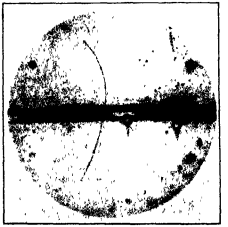

FIG. 3. THE FIRST TRACK OF A POSITIVE ELECTRON EVER RECOGNIZED. (ANDERSON.)

an illustration may be seen in Fig 7 Now the famous track which Anderson observed was definitely of the thin and slender type, scantily furnished with droplets; and any one of experience would say on looking at it, "Here is the track of an electron!"

This by itself is not conclusive, for according to theory a proton moving with enormous speed—much greater than any yet attained in the laboratory—would likewise produce a thin and scanty track Here, however, the curvature of the path bears testimony. So fast a proton would not be so much deflected in this magnetic field, and we can state as a fact of experience that if a proton or an alpha-particle in such a field had left behind it a trail of such a curvature, that trail would have been much fatter and thicker than the one which Anderson observed Not only would it have been thicker, it would also have been much shorter, for the massive particle would have squandered its energy so rapidly in forming ions that its course would have come to an end in five millimeters, whereas the actual path on one side of the plate in Fig. 3 is five centimeters long

Anderson's particle was therefore much more like an electron, in everything but the sign of its charge, than it was like a proton or an alpha-particle Now the question arises How accurately can we estimate its charge and its mass from the length and the appearance of its track? This, as one can readily imagine, is a very intricate theoretical problem It will always be an important problem, but luckily it is not so urgent as it used to seem; for Thibaud has succeeded in applying one of the classical deflection methods of measuring charge-to-mass ratio, and it is altogether likely that eventually we shall have as accurate a value of this ratio for positive as we do for negative electrons. Thibaud thus far has published only the statement that the two values are of the same order of magnitude; one of his colleagues assured me that the value for positive electrons is almost certainly between one half and twice, and quite certainly between one tenth and ten times, that for the negative electron This is already a great advance over the previous estimates, and an important result in itself, the ratio for the next lightest of positive particles, the one hitherto supposed the lightest of all, is only 0054 as great as that of electrons

We now take leave of Anderson's particle, probably the most famous individual corpuscle in the history of physics; one wishes it were preserved in a museum, but of course Anderson could not capture it, and alas, we must perhaps suppose that it no longer exists, for according to many theorists, it must long since have merged with a negative electron and vanished into light The scene now shifts to the Cavendish Laboratory, where Blackett and Occhialini were also studying cosmic rays with an expansion-chamber lying on its side They had done what every one at Monte Carlo would like to do, they had contrived not to make any bets, not to wager the price of a single photographic plate, excepting at moments when there was a far better than average chance of drawing a prize. This they achieved by setting up a pair of Geiger counters, one on each side of the cloud-chamber, and a mechanism so contrived that the chamber would expand when and only when both of the counters should react at the same or nearly the same instant Such a coincidence might mean that a single ionizing particle had passed through both the counters; if so, its track would appear in the cloud-chamber lying between Or again it might mean that somewhere in the neighborhood there had been a sort of atomic explosion, with ionizing particles hurled in all directions; in which case, some of these might pass through the cloud-chamber itself. In fact they got a number of photographs such as Fig. 4, showing what they call by the well-chosen name of "showers": bursts of many tracks, all radi-

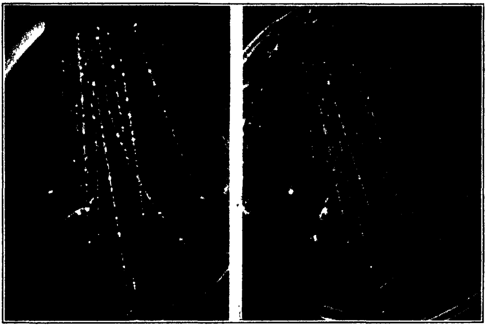

FIG. 4. A COSMIC RAY "SHOWER" OF SOME 16 TRACKS
PHOTOGRAPHED FROM TWO VIEW POINTS. THE TWO TRACKS WHICH ARE CONCAVE TO THE RIGHT ARE DUE TO POSITIVE ELECTRONS (BLACKETT AND OCCHIALINI.)

ating from a single point which generally lies somewhere in the mass of metal surrounding the chamber. There are many interesting features of these showers; but we are here concerned with only one—the occurrence of tracks which have the peculiar aspect and appearance of electron-tracks, and some of which are curved one way and some the other. This might mean that some negative electrons are shooting out from the radiant point and some are shooting in; but it is surely one of the most deep-seated of human convictions that when tracks are seen to diverge from a common point, the objects which made them must have traveled outward and not inward, unless for one which may have provoked the flying-asunder of the rest. Or, as Anderson puts it: It is not likely that such a lot of particles would have an appointment to meet at the same place at the same time! We therefore conclude from these pictures that electrons of both the signs sprang out from these explosions.

Thus far, Pasadena and Cambridge had waited for the cosmic rays to furnish them with positive electrons, but now they began to find out how to produce these at will, and this in importance was not far behind the discovery itself. Chadwick and Blackett and Occhialini were the first to manufacture (if so crude a word may be permitted) the positive electron. Just outside the wall of the Wilson chamber they placed a piece of beryllium exposed to constant bombardment by the alpha-rays of polonium, this, as had been discovered only a little earlier, is a "source" from which both neutrons and high-frequency photons are continually being emitted; I will denote it by the symbol "Po + Be," which is becoming the usage in France. Just inside the wall they put a piece of lead. The glass was no obstacle to the great majority of the neutrons and the photons; many of them impinged on the lead, and at the expansions it was observed that cloud-tracks sprang forth from the metal, and that they had the specific appearance of electron-tracks,

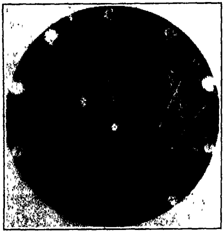

FIG 5. A COSMIC-RAY SHOWER OF 5 TRACKS, 2 OF POSITIVE AND 3 OF NEGATIVE ELECTRONS (ANDERSON.)

and that some of them were curved one way in the magnetic field and some the other. Just the same thing was shortly thereafter observed by Meitner and Philipp in Dahlem, except that they had the source "Po + Be" within the chamber itself enclosed in a capsule of brass At the expansions they found electron-tracks arising from the capsule, and some of these were curved one way and some the other

The pictures thus imply that electrons of both signs are expelled from lead or brass by the rays of the "Po + Be" source. Still, it may be contended that what appear to be tracks of positives coming forth from the metal are really tracks of negatives coming from the far side of the chamber or out of the gas itself and plunging into the metal. In view of the other evidence for positive electrons, this probably seems a far-fetched idea, but there is nothing intrinsically incredible about it, and if there were no other evidence, it would be the more natural and acceptable idea Indeed it appears to have delayed the recognition of the positive electron by months and to have shifted the discovery across the sea. As early as the spring of 1932, M. F Joliot and Mme. Joliot (Irene Curie), in the Institut du Radium in Paris, were admitting the rays of Po + Be into expansion-chambers, and photographing the tracks which occurred in the gas; and they observed and remarked that some of these appeared to be the tracks of electrons traveling backwards toward the source! That worried them a good deal, and they invented a two-stage process to explain it, whereby neutrons shooting forward from the source should cause atoms of the gas to send out photons, and these photons should be absorbed in other atoms and expel the retrograde electrons. It now seems quite beyond doubt that Curie and Joliot were observing forward-moving positive electrons instead of backward-moving negatives, and indeed they helped to prove it. Later on, for instance, they repeated the experiment of Chadwick and his colleagues which I have been describing, first with a piece of lead exposed to the rays of Po + Be, and then with an exactly similar piece of aluminium. Nothing whatever had been changed about the chamber, except the nature of the metal, but there were very many more of these peculiar tracks proceeding from the metal when it was lead than when it was aluminium The most

FIG. 6. TRACKS OF AN ELECTRON-PAIR ARISING IN ARGON EXPOSED TO GAMMA-RAYS, AND PROBABLY CREATED FROM A PHOTON AT ITS APPROACH TO AN ARGON NUCLEUS. (CURIE AND JOLIOT.)

conclusive evidence, however, had earlier been supplied by the physicists of Cambridge: they adopted Anderson's test, setting a thin sheet of metal close behind the lead where it would intercept the tracks; and several times it was observed that where a track passed through the sheet, its curvature was greater on the far side, showing that the corpuscle which made it had indeed proceeded from the lead.

Taking it now for proved that there are such things as positive electrons, let us examine what more is known or conjectured about them.

A question comes up immediately: In this mixture of neutrons and photons from the Po + Be source which ejects the positive electrons from lead, are the neutrons or the photons responsible? One might prefer the neutrons, on the plausible ground that these are newly discovered particles of which almost anything is still believable, while photons have been known for quite a while without any one observing that they are able to engender positive electrons; but apparently one would be wrong. Curie and Joliot found that if they inserted metal screens between the Po + Be source and the leaden block, the number of positive electrons evoked from the lead was reduced not at all in the proportion in which the neutrons were cut off by the screen, but more nearly in the proportion in which the photons were cut off, and this certainly settles that the last-named are chiefly responsible, if not indeed altogether. There is another fact which may be relevant to the issue, and anyhow is of the first importance in itself. It is possible to generate positive electrons by streams of gamma-rays—high-energy photons—coming from radioactive bodies which do not emit any detectable number of neutrons at all.

Here are the data in a brief table, in which the first column contains the names of various sources of gamma-rays; the second, the energy-values (in millions of electron-volts) of the individual

FIG. 7. TRACK OF A 3,000,000-VOLT POSITIVE ELECTRON SPRINGING FROM ALUMINIUM EXPOSED TO ALPHA RAYS (THE LONG TRACK CONCAVE TO THE RIGHT, THE THICK TRACK IS THAT OF A PROTON, THE OTHERS OF NEGATIVE ELECTRONS. (JOLIOT AND CURIE.)

photons of these rays; the third, the names of various metals; the fourth, the number of positive electrons per hundred negatives, ejected from these metals by these gamma-rays, and the fifth, the authorities.

Po + Be	5	uranium	40	Joliots
		lead	30	Joliots
		lead	35	Chadwick
		copper	18	Joliots
		aluminum	5	Joliots
ThC″	2.6	lead	8	Joliots
		lead	4	Chadwick
Ra(B + C)	1.0–2.2	lead	3	Grinberg
Po	0.85	lead	0	Meitner-Philipp

The percentages in the fourth column give at the moment our best available notion about the relative plentifulness of the positive electrons, ejected from the several metals by the several kinds of rays.[2] One would prefer to have the

[2] Meitner and Philipp give an estimate of one third for the proportion of positives to negatives when brass is exposed to (Po + Be), this does not agree well with the value quoted for copper, and they qualify it as a mere

total number of positives per unit intensity of the infalling rays, but that is not available at present—perhaps because of the difficulty of measuring these intensities. It must be kept in mind that the data usually consist in observations of a few hundred or even a few dozen cloud-tracks, so that the accuracy of these percentages can not be great

We note, then, that with lead the percentage of positive electrons goes up rapidly with increasing photon-energy, and that with photons of five-million-electron-volt energy the percentage goes up rapidly with the nuclear mass of the bombarded atoms Both of these rules are in harmony with a current theory of the generation of positive electrons So are other facts of experience, but before stating them, I will state the central idea of the theory, which is simple and spectacular. A positive electron is supposed to come into being by virtue of a transmutation more drastic and amazing than any hitherto effected or imagined *it is supposed that a photon transmutes itself into a pair of electrons, one of each sign*

Such a transmutation—if it happens—leaves the net charge of the universe unchanged. If in addition it is to leave the net energy of the universe unaltered, we must invoke the principle of the equivalence of energy and mass. Einstein's relation,

$$E = mc^2$$

where E stands for energy and m for mass and c for the speed of light *in vacuo* The masses of two electrons at rest, when translated into units of energy according to Einstein's relation, amount to about one million electron-volts ($1.02 \cdot 10^6$ is more nearly right, but the even million is a good round number perfectly satisfactory for these data). The residue of the energy of the photon—its original energy, minus this million—then remains over, it might go into kinetic energy of the electrons, or into a new photon, or divide itself between these forms Here are testable consequences of the theory If this central idea is right, then positive and negative electrons should spring forth in pairs, and the energy of each electron-pair, and *a fortiori* that of any positive electron by itself, should never come within one million volts of the energy of the primary photon

Now it is indeed a fact that positive electrons are often paired with negatives, in the sense that one of each sign appears to spring from a single point on the irradiated metal Fig 6 is a wonderful photograph in which a pair is seen to start from a point in the gas of the chamber There are always some positives which are apparently unpaired, but one can explain this away by saying that probably the associated negative got caught in the metal There is also always an excess of negatives, as the table has shown, but one can always say that this excess consists of electrons expelled from the atoms by the photons in ordinary collisions Finally, it is an empirical rule that the kinetic energy of an electron-pair or of an isolated positive never comes within a million volts of that of the primary photons. Everybody who has been producing positive electrons has been looking for exceptions to that rule, and thus far, I believe, no unimpeachable exception has been found. Thus, Anderson and Neddermeyer observed twenty-two pairs and thirteen isolated positives, and found only one case of a pair having more than the proper maximum energy; and this, as they say, might have been a case of two independent electrons happening to start from points close together. Another corollary of the theory is that photons of energy less than one million electron-volts ought not to produce any positives at all; and this is borne out by the nega-

estimate (*ueberschlagsmässige Rechnung*) Anderson finds as many positives as negatives among the ionizing particles of the cosmic rays, which perhaps is to be taken as meaning that these are due to photons of very high energy-values indeed

tive result obtained with the gamma-rays of polonium

In this imagined process of transmutation, charge is conserved and energy is conserved, in conformity with two familiar principles. There is yet another *principle of conservation*, older than either, it is Newton's third law, that the total momentum of the world ought to remain invariable Now if we attempt to apply this principle to the pictured process, we reach a disconcerting conclusion if a photon in the depths of space should convert itself spontaneously into two electrons, momentum and energy could not possibly both be conserved[3] This seems at first to impair the theory greatly, as it is not without the greatest reluctance that physicists would forego the conservation of momentum We recall, however, that positive electrons have not been shown to spring into existence in the depths of space, but only where a beam of photons is traversing a sheet of matter This suggests that the nucleus of some atom enters into the process, to the extent of receiving enough momentum to balance the budget, and inversely that the process can not occur unless there is a near-by atom available to serve this purpose In the fully developed theory, indeed, an atom is always introduced to play this rôle

There is another set of data with which the theory attempts to cope, and this pertains to the absorption of high-frequency photons by heavy elements There are three well-known kinds of adventure which may befall a photon when it dives into a metal. It may simply be deflected, without sensible change of energy, or it may have what is known as a Compton collision with a nearly free electron, and be deflected with a loss of energy; or it may be utterly swallowed up in an atom, and expel a photoelectron If a beam of x-rays or gamma-rays is sent through a sheet of metal, any photon which undergoes any one of these adventures is removed from the beam; and accordingly it may be said that there are three modes of absorption. Now quite a good deal is known about these three, and it can safely be said that for most elements and most x-rays or gamma-rays, they constitute all the absorption which occurs However, it was discovered, three or four or five years ago, that with very heavy elements and very high-frequency gamma-rays, the total absorption is greater than can be ascribed to these three modes put together There must consequently be an extra mode, and people have been calling it "nuclear absorption" on the general ground that the nucleus must be to blame for anything that we do not fully understand[4]

It has lately occurred to several physicists that this extra absorption is simply that of the photons which convert themselves into electron-pairs This idea is in general agreement with the facts that the extra absorption increases rapidly with frequency of gamma-rays and atomic weight of metal, which, as I have just been saying, is also the rule for the production of positive electrons. Moreover, it agrees with the fact that no one has yet observed this additional absorption with gamma-rays of lesser energy than one million electron-volts Indeed, there is a very recent and interesting note by a physicist, Gentner, at Paris, who plots an experimental curve of extra absorption *versus* frequency and then extrapolates it, and finds that the extrapolated curve comes down to zero at just about the frequency where the energy of

[3] If we postulate both conservation of energy and conservation of momentum, it follows (the reckoning is easy) that the speed of one at least of the electrons is superior to that of light, which is contrary to the doctrine of relativity on which the calculation is based, and therefore a *reductio ad absurdum*.

[4] With this extra absorption there goes an extra "scattering" or emission of gamma-rays from the metal, and it appears that some of these have the proper energy to be attributed to a process which is the reverse of the one already described—that is to say, the coalescence of a pair of electrons of opposite sign into a corpuscle of light. Not all the measurements, however, are concordant.

the photon amounts to one million electron-volts—just the minimum amount, that is to say, which should suffice to create an electron-pair. There are further confirmations. Oppenheimer and Plesset have been working out the quantum-mechanical theory of this imagined process of the transmutation of light into electron-pairs, and have published a brief account of its conclusions, in the course of which they say "Numerical calculation for the case of the gamma-rays of thorium C" . . gives an excess absorption of about 25 per cent. of the Klein-Nishina [*i.e.*, the Compton-collision] absorption in lead and 15 per cent. in tin, in excellent agreement with experiment."

Well! when a theorist of the rank of Oppenheimer speaks of "excellent agreement with experiment" it is necessary to take the theory seriously, and this is a theory of the first importance. Here we witness, it may be, the disappearance of the last apparent barrier in physics: the barrier which seemed to separate the substance of electricity and matter from the substance of light. We have long been accustomed to the idea, and perhaps we shall soon be accustomed to the fact, of every sort of transmutation among the divers elements of matter; but the idea of transmutation between matter and light is one which will require years to realize in all its implications. Perhaps, however, it would be well to be a little cautious, awaiting the results of further tests which the quantum-mechanical theory invites[5]; not yet is it safe to discard the idea that these electrons, of whichever sign, may simply have been expelled by the photons from atom-nuclei where they have previously been existing. I therefore bring this story to its end not with a paean of triumph to the theory, but with a description of the latest and most potent method of producing positive electrons, discovered by the Joliots hardly more than half a year ago.

What the Joliots observed was the emission of positive electrons from a leaf of aluminium foil, exposed to the bombardment of alpha-particles from polonium. Later on they observed the like effect when targets of boron and of beryllium were substituted for the aluminium (It is easy to confuse this observation with the earlier one, in which the rays emitted by the bombarded beryllium were found to evoke positive electrons from a second piece of metal; but in this later work the positives which were observed came forth from the beryllium itself). It may well be an accompaniment of transmutation, for the alpha-particles which cause it likewise possess the power of transmuting all three metals. It is not a universal effect, for it is not observed when lithium is substituted for the aluminium (this proving incidentally that the positives are not from the polonium itself). From aluminium the number of positives emitted is of the order of one to every couple of million of incident alpha-corpuscles; and several months ago Joliot composed a source capable of producing thirty thousand positive electrons to the second. Somewhat later, Thibaud got streams of positive electrons from capsules of radioactive salts enclosed in silver or lead—streams sufficiently strong to cause a fluorescent screen to shine with a light bright enough to be photographed. By comparison with the mighty torrents of negative electrons which flow in any technical vacuum tube, these feeble currents may seem trivial. That, however, is not the proper standard of comparison. One should rather say that in the autumn of 1932 positive electrons were being observed at the rate of three or four a year, and already in the summer of 1933 this rate had been enhanced to thirty thousand in the second.

[5] Thus, the theory predicts the distribution-in-direction of the electrons created by the photons, and the division of the kinetic energy between the positive and negative members of a pair; and also (according to Furry and Carlson) it predicts that electrons having kinetic energy greater than a million electron-volts should be found able to create new electron-pairs.

THE TRANSMUTATION OF THE ATOM[1]

By LORD RUTHERFORD

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THE possibility of the transmutation of one kind of matter into another has always exerted a strong fascination on the human mind since the early days of science. During the past thirty years, I have been actively engaged in investigations on various aspects of this question, and I shall try to give you here a brief account of the essential nature of the problem of transmutation and of the methods that have been devised to extend our knowledge It is a problem that is attracting much attention in the scientific world to-day, and during the last decade there has been a vigorous and sustained attack on it. Experiments, some on a large and costly scale, are now being carried out in many laboratories throughout the world to advance our knowledge

The first successful experiments in transmutation are comparatively recent, dating back to the year 1919, but in a sense the problem is a very old one and has been the subject of much thought and investigation from the time when science was in its infancy You have all heard of the alchemists, who were in fact the first chemical investigators, and the search for a substance called the philosopher's stone whereby it was hoped one element could be changed into another. Looking back from the standpoint of our knowledge to-day, we see that there was no hope of success in this quest with the limited laboratory appliances and methods available in those days, and that the experimental evidence brought forward in its support was of a very doubtful and meager character. However, the persistence of this idea through the centuries was mainly due to a philosophical conception of the nature of matter, based on the writings of Aristotle, which had a very great influence on the outlook of the intellectual world in the Middle Ages According to Aristotle, all matter consisted of a fundamental substance, primordial matter, together with a mixture of the four elements called earth, air, fire and water One substance differed from another only in the relative combination of these hypothetical elements. On these views, it appeared almost self-evident that one substance could be changed into another if only a suitable method could be found to alter the amount of one or more of these constituents Naturally, the hope of changing the base metals into the noble element gold assumed a prominent place, and from time to time men arose who claimed that they had discovered the secret of changing copper, lead or other metals into gold In times of monetary stress, these alchemists were often employed by rulers to restore the finances of the state by making gold. They often succeeded in making a substance that had the appearance of gold, but in general the net result of their experiments was a debasement of the coinage. Even after the possibility of producing transmutation by ordinary laboratory methods had long been exploded, the old ideas persisted in the general mind, so that even to-day impostors or deluded men occasionally appear who claim to have a recipe for making gold, but the only gold they make is extracted from the pockets of their credulous supporters. The poverty

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of imagination of this class of charlatan is shown by the fact that they have not at once claimed to produce instead of gold the more rare and costly elements like platinum and radium

The great work of the chemists of the nineteenth century had shown that matter could be resolved into eighty or more distinct elements, and that the atoms composing each of these elements appeared to be indestructible and unchangeable under the action of the physical and chemical forces at their command. The ancient notion of transmutation proved impossible to realize until new and more powerful methods were available At the same time it became clear from general chemical evidence, such as is embodied in the Periodic Table of the elements, that the atoms of the elements are not unrelated but must possess in some respects very similar structures This idea received strong support from the fundamental discovery of the electron in 1897, mainly due to the work of Sir J J Thomson The electron, which carried a negative charge of electricity, was found to have a minute mass—only about 1/1840 of the mass of the lightest atom hydrogen—and to be a constituent of all atoms One or more of these light electrons could be struck out of the atom either by the action of swift particles or by ultra-violet radiation or x-rays. The resulting atom acquired a positive charge and had different properties from the neutral uncharged atom The change of properties was, however, only momentary, for in a very short interval another electron fell into the atom and filled the vacant place, and the atom was restored to its original state. General evidence indicates that it is impossible to cause a *lasting* transmutation of the atom by removing or adding electrons to the outside of the atom. Whatever effect is produced by such action is only of a fleeting character and has no permanent effect on the structure of the atom

The discovery of the radioactivity of uranium by Becquerel in 1896 was another landmark in the history of our subject. The experiments of Rutherford and Soddy in 1903 showed clearly that radioactivity was a direct manifestation of atomic instability It was shown that occasionally an atom broke up with explosive violence, hurling out with great swiftness either a massive particle called the α-particle, or a swift electron of light mass called the β-particle. As a consequence of this explosion, the residual atom had entirely different physical and chemical properties from the parent atom It was found that the successive transformations of the two elements uranium and thorium gave rise to thirty or more new elements which had radioactive properties Radium is the best-known example of these many elements which originate from the successive transformations of the element uranium The then rare gas helium was found by Ramsay and Soddy to be generated by the transformation of the radium atoms, and we now know that this helium arises from the α-particles, which are charged helium atoms expelled from the exploding atom The study of the swift α- and β-particles and the pentrating x-rays brought out clearly the extraordinary intensity of these atomic explosions, in which energy was emitted of the order of one million times that generated by a combination of two atoms in the most violent explosive known

This transformation of the radioactive atoms is spontaneous and uncontrollable; neither extremes of heat or cold have any effect on the rate of transformation or on the energy of the expelled particles. At the moment, no definite explanation can be given why the atoms of uranium break up. We have to regard their transformation as a natural process which is governed by the laws of chance. This property of spontaneous transmutation is most strongly shown by the two heaviest known ele-

ments, uranium and thorium, and the radioactive elements which arise from them. Only three other elements have shown this property, and then only to a minute degree compared with uranium or thorium. All the rest of the elements appear to be permanently stable under normal conditions on the surface of our earth; it seems, therefore, that the idea of the immutability of the elements is true under normal conditions for the great majority of our elements.

A further attack on this problem had to await a better understanding of the essential structure of all atoms. It is now clear that all the atoms of the elements are in a sense electrical structures built on the same general pattern. At the center of each atom is a minute but massive nucleus which has a resultant charge of so many units of positive electricity varying from 1 to 92 for the various atoms. At a distance from the nucleus is a distribution of negative electrons in whirling motion, whose number is equal to the number of positive charges carried by the nucleus. It must be borne in mind that the radius of the nucleus, supposed spherical, is extremely minute and in general less than one ten-thousandth part of the radius of the atom as a whole. Yet this diminutive nucleus not only contains nearly the whole mass of the atom, but through its nuclear charge controls the number and motions of the external or planetary electrons, as they have been termed from analogy with our solar system. Since the ordinary physical and chemical properties of an element are determined by the charge on the nucleus and not by its mass, the atoms of a given element may not be all identical in mass or weight, although they must have an identical charge on each nucleus. We now know, largely through the work of Aston, that most of the ordinary elements are composed of a mixture of atoms of different masses called isotopes. For example, the atoms of the light element lithium—which, we shall show later, can be disintegrated by certain agencies—consist of two isotopes, of masses 6 and 7 times the mass of the hydrogen atom, the isotope of mass 7 being more abundant. We shall see that this isotopic constitution of many elements has to be taken into account in interpreting the types of transformation that can be effected. For example, while one isotope may be readily transmuted, the other isotope may be either unaffected or transformed in a different way.

The broad features of the constitution of all atoms are now well established. As a result of the splendid work of Bohr and those who have followed him, we are able to understand the arrangement and motions of the planetary electrons and the way in which light or x-rays are emitted when the atom is disturbed. Unfortunately, we have much less information about the constitution of the minute central nucleus. We know the value of the nuclear charge and the mass of each atom, but we have no precise information on the nature and arrangement of the particles composing it. Until a year or so ago, it was generally supposed that the nucleus of an atom was ultimately composed of two electrical units, the negative electrons of small mass and the positively charged protons of mass 1. At the same time it became clear that secondary units were also present and that the helium nucleus of mass 4—the α-particle—played a prominent part. Recently, however, we have had to extend our views, for undoubted evidence has been obtained of the existence of a new type of particle called the neutron which has a mass about 1 but no electrical charge. At the same time, the discovery this year of what is believed to be the positive electron of light mass—the counterpart of the negative electron—has complicated the problem. However, we may, I think, assume with some confidence that the nucleus of a heavy atom is in general composed of a large

number of particles, some charged like the α-particle and proton, and others, like the neutron, electrically neutral. These are held together by powerful forces in an extraordinarily minute volume and form a very stable structure. We have, however, little to guide us in seeking a more detailed knowledge of the number, arrangements and motions of these constituent particles.

In order to transmute one atom into another, it appears essential to alter the charge on the nucleus. This can be done in imagination by adding another charged particle, say a proton or α-particle, to the nucleus, or removing a charged particle from it. We must, however, bear in mind that the nucleus is a strongly guarded structure held firmly together by strong attractive forces. In order to disrupt a nucleus, it thus seemed likely that very intense forces must be brought to bear directly upon it. One method of accomplishing this is to bombard the nucleus with very swift particles. Now the α-particle, which is spontaneously ejected from radium, is one of the most energetic particles known to science. It was recognized that if a stream of swift α-particles fell on matter, there was a small chance that one out of a great number might have an almost head-on collision with a nucleus. Under these conditions it must approach very near to it before it was turned back by the strong repulsive forces due to the electric charges on the two particles. It must be emphasized that the close collision of an α-particle with a nucleus involves the setting up of gigantic forces between the two nuclei concerned. In the case of light atoms where the nuclear charge is small, calculation indicated that the colliding α-particle, if it did not enter the struck nucleus, must at least approach sufficiently near to distort greatly its electrical structure. Under such disturbing forces, the nucleus might be expected to become unstable and then break up into other nuclei. Actuated by these general ideas, I made in 1919 some experiments to test whether any evidence of transformation could be obtained when α-particles were used to bombard matter. The experiments were of a simple type; a preparation of radium served as a source of α-rays and the scintillation method was used to detect the presence of any new types of particles. It is well known that each α-particle falling on a preparation of zinc sulfide gives a flash of light, a scintillation, which is easily seen in a darkened room, and it was to be expected that any fast charged particle liberated from the bombarded matter would indicate its presence by a scintillation. When α-particles were used to bombard the gas oxygen, no new effect was observed. When, however, nitrogen gas was substituted, a number of scintillations were observed far beyond the distance of travel of the α-particles Special experiments showed that these scintillations were produced by charged hydrogen atoms which we now call protons. The appearance of fast protons in these experiments could only be explained by supposing that they arose from the transformation of some of the nitrogen nuclei as a result of α-particle bombardment. This was the first time that definite evidence was obtained that an atom could be transformed by artificial methods. In the light of later experiments by Blackett, the general mechanism of this transformation became clear. It was found that the α-particle must actually penetrate into the nitrogen nucleus and be captured by it. As a consequence of this profound disturbanee, a proton was ejected with high speed from the new nucleus. Let us for a moment consider the simple arithmetic of this process. The mass of the nitrogen nucleus is 14 and its nuclear charge 7 units. The capture of an α-particle of mass 4 and nuclear charge 2 raises the mass to 18 and the charge to 9, while the loss of a

proton of mass 1 and charge 1 results in the formation of an atom of mass 17 and charge 8. Now the oxygen nucleus has a charge 8, so that as a result of the interaction with an α-particle, the nitrogen nucleus is changed into a nucleus of oxygen. It will be noted that the mass of the oxygen nucleus formed in this way is 17 and not 16 as ordinarily observed. It was only later that the presence of an isotope of mass 17 in small quantity in ordinary oxygen was disclosed by direct experiments of another kind. In subsequent investigations with Dr. Chadwick, the methods of observation were much improved and it became clear that at least twelve light elements could be transformed by α-particle bombardment, and in every case protons were ejected, the number and speed varying from element to element. It seems probable that the process of transformation is similar in all cases to that found for nitrogen. The α-particle is captured and the new atom that is formed has a mass 3 units greater and a charge of 1 unit higher than the original atom. In other words, we have succeeded with each of these twelve elements in turning one of their atoms into the atom of the element next higher in the normal order of the elements.

It must be borne in mind that the amount of new matter formed in this way is exceedingly minute—far too small to examine by ordinary chemical methods. Success has only been obtained by the development of delicate methods of counting single atoms of matter. On account of the minute target area of a nucleus, the chance of a direct hit by an α-particle is very small. In the case of nitrogen, only about one α-particle in 100,000 is effective in causing a transformation, and for the element aluminium the chance is still smaller—about one in a million. Of course, the α-particles in these experiments are not aimed at the nuclei, but are emitted at random in all directions, and occasionally one of them by chance happens to approach closely enough to a nucleus to be captured.

While a number of light elements could be transformed by these methods, some, like lithium, carbon and oxygen, appeared to be unchanged by α-particle bombardment. The light element beryllium, however, showed a strange effect: no protons could be detected, but Bothe noticed the emission of a penetrating radiation which M. and Mme. Curie-Joliot found had unusual properties. Chadwick showed that this radiation consisted of a stream of fast particles of a new type which he named "neutrons." This new particle has about the same mass 1 as the proton, but has no electrical charge. The transformation of beryllium is thus of a different kind from that of most of the other light elements. As before, the α-particle is captured, but a high-speed neutron—not a proton—is expelled. By this process the nucleus of beryllium of mass 9 is changed into an atom of carbon accompanied by the ejection of a neutron.

This strange type of projectile has remarkable properties. On account of the absence of charge, the neutron is able to pass freely through atoms of matter with little if any loss of energy. It only makes its presence manifest when it collides with the nucleus of another atom. Feather has shown that fast neutrons are in turn effective in producing transformations of novel types in other elements. For example, he finds that both oxygen and nitrogen can be transformed with the emission of fast α-particles, while recently Harkins has shown that neutrons can also transform carbon and neon. The effect of the neutron on oxygen is of special interest, as the oxygen nucleus appears to be quite unaffected by bombardment either by α-particles or protons.

So far we have dealt with the transformations produced by fast particles which are themselves derived from the

spontaneous disintegration of radioactive elements. It soon became clear, however, that in order to extend our knowledge of this subject, far more abundant streams of fast projectiles of different kinds were essential. It was well known that the passage of an electric discharge through a gas at low pressure gives rise to a multitude of charged atoms and molecules of various kinds. If the charged atoms obtained in this way were accelerated in a vacuum by passing through a strong electric field, we might hope to obtain a copious stream of fast projectiles of different kinds for bombardment purposes. For example, when a discharge is passed through hydrogen it is easy to produce a stream of as many projectiles as are emitted by 100,000 grams of radium in the same time. By the use of high voltages, of the order of one million volts, it seemed likely that we could hope to obtain sufficiently fast particles to effect atomic transformations. In order to realize this purpose experimentally, elaborate electrical apparatus is required to generate the high voltage to be applied to the accelerating tube, and very fast pumps to keep the vacuum so low that no discharge can pass. After several years' hard work, Cockcroft and Walton in Cambridge succeeded in obtaining a strong beam of protons accelerated by half a million volts, suitable for bombarding purposes. When the accelerated protons were allowed to fall on a lithium target, a number of fast particles resembling α-particles were observed to emerge through a thin window opposite the target. These particles were counted by the scintillation method already referred to and also by automatic electrical methods which had been developed by Wynn Williams. It was soon shown that the particles from lithium were veritable α-particles, *i.e.*, helium nuclei of mass 4. These experiments of Cockcroft and Walton are of great interest and importance, for it is the first time that it has been shown possible to disrupt an atom by the use of fast particles produced by artificial methods in the laboratory. The general character of this transformation is now clear. Occasionally a proton of mass 1 enters the lithium nucleus of mass 7, and this then breaks up into two α-particles, each of mass 4. If this be true, the α-particles should fly off in nearly opposite directions. This has been verified and is beautifully shown in the photographs of the tracks of the α-particles obtained by Kirchner in Munich and by Dee and Walton in Cambridge.

We are not able to follow in detail the complicated and intense reactions which must occur in this transformation, for we are not yet certain of the constitution of the lithium nucleus before the capture of the bombarding proton. There seems to be no doubt that one at least of the helium nuclei ejected must have been formed *in situ* in the nucleus from the constituent neutrons and protons. In these types of nuclear reaction, more than one type of transformation may take place, and there is strong evidence that this is so in lithium, but the exact nature of these transformations is still unknown.

Cockcroft and Walton found that the number of α-particles observed increased rapidly with voltage, and was very large at 500,000 volts, while Oliphant has shown that the transformation of lithium can readily be detected for an accelerating voltage of only 30,000 volts. This result would have been difficult to understand on the old ideas, but is quite in accord with the new wave theory of matter. Gamow has shown that there is a chance, even if a very small one, for a comparatively slow particle to penetrate the strong electric barrier round the nucleus.

Cockcroft and Walton found that not only lithium, but also boron and fluorine, emitted α-particles under proton bombardment. The exact nature of

these transformations has not yet been settled, but it may be that the boron nucleus of mass 11 captures a proton and then breaks up into three α-particles, each of mass 4. In general it appears that proton bombardment leads to the emission of α-particles and the formation of elements of smaller mass, while α-particle bombardment causes a rise in mass of the resulting element.

I must now say a few words about some very important experiments with a new type of projectile which have been carried out by Professor Lawrence in the University of California. The work of a number of scientific men in the United States in the last two years has shown that ordinary hydrogen of mass 1 contains in very small quantity another isotope of mass 2. Although the quantity of this heavy hydrogen is only about one part in 6,000 of the main isotope, yet Professor Lewis, of the University of California, has succeeded by electrolytic methods in obtaining quantities of this heavy hydrogen in nearly a pure state. When we consider what a large part hydrogen plays in the structure of organic molecules, I need not emphasize the extraordinary interest of this discovery, both to chemistry and physics. This heavy hydrogen has the same chemical properties as ordinary hydrogen, but the water formed from it has a density 10 to 11 per cent. higher than ordinary water, and has also a different boiling and freezing point. Just before these experiments of Professor Lewis were undertaken, his colleague, Professor Lawrence, had devised a very ingenious method, depending on multiple acceleration, of obtaining protons of energy as high as 2 million volts. When this heavy hydrogen was used, the projectiles of mass 2 were found even more effective than protons in causing disintegration in many elements. For example, lithium was transformed into two α-particles each of speed greater than any α-particle observed from radioactive substances. In this case, the isotope of mass 6 appears to be involved. The capture of the hydrogen nucleus of mass 2 leads to the break-up of the nucleus into two α-particles flying off in opposite directions. This has been amply verified by the beautiful photographs obtained by Dee and Walton. In addition, many other atoms were found to be transformed by the same agency with the emission of α-particles, and in some cases very fast protons were also observed. The interpretation of this effect, which is shown even by some heavy elements, will surely prove of great importance in further developments. Professor Lewis kindly sent me some of this heavy water, and Dr. Oliphant and I have been able to confirm and extend these results with lithium, using only 100,000 volts on the discharge tube. There can be no doubt that this new kind of projectile will prove of great service in our attack on the transformation of the elements. It will be of great interest to compare in detail the types of transformation that arise from the use of these two kinds of hydrogen as projectiles.

It is interesting to consider the energy changes involved in these transformations. We have seen that a proton of energy corresponding to 30,000 volts can effect the transformation of lithium into two fast α-particles, which together have an energy equivalent of more than 16 million volts. Considering the individual process, the output of energy in the transmutation is more than 500 times greater than the energy carried by the proton. There is thus a great gain of energy in the single transmutation, but we must not forget that on an average more than 1,000 million protons of equal energy must be fired into the lithium before one happens to hit and enter the lithium nucleus. It is clear in this case that on the whole the energy derived from transmutation of the atom is small compared with the energy of the bom-

barding particles. There thus seems to be little prospect that we can hope to obtain a new source of power by these processes. It has sometimes been suggested, from analogy with ordinary explosives, that the transmutation of one atom might cause the transmutation of a neighboring nucleus, so that the explosion would spread throughout all the material. If this were true, we should long ago have had a gigantic explosion in our laboratories with no one remaining to tell the tale. The absence of these accidents indicates, as we should expect, that the explosion is confined to the individual nucleus and does not spread to the neighboring nuclei, which may be regarded as relatively far removed from the center of the explosion

The general law of conservation of energy appears to hold in these intense nuclear explosions On modern views there is a close connection between the mass of a body and the energy stored up in it. Any decrease of mass of a system is accompanied by the emission of a definite quantity of energy in one of its characteristic forms—for example, in the form of energy of motion of one or more of the particles concerned, or in the emission of radiation in the form of x-rays, or possibly both types of energy together. Now, in the lithium transformation, the relative masses of the proton, nucleus and α-particle are known with considerable accuracy. When we take into account the change of mass of the system before and after the nuclear explosion, and the kinetic energy of the expelled α-particles, we find that there is a close balance showing that this generalized form of conservation of energy holds within the accuracy of the observations. It is to be hoped that this law of conservation will prove a reliable guide in interpreting other types of nuclear reactions.

My listeners may quite naturally ask why these experiments on transmutation should excite such interest in the scientific world. It is not that the experimenter is searching for a new source of power or the production of rare and costly elements by new methods. The real reason lies deeper, and is bound up with the urge and fascination of a search into one of the deepest secrets of nature. Until a few years ago, we had to be content with the knowledge that the whole of matter in the universe, including our own bodies, was made up of ninety or more distinct chemical elements, but we had little definite knowledge of the inner structure of their atoms or of the processes by which one element could be converted into another Now, for the first time, we are able to investigate these problems by direct experiments in the laboratory, and we are hopeful we shall soon add widely to our knowledge. The information so gained can not but widen our outlook on the nature of matter, but must also have a direct bearing on many problems of cosmical physics For example, in the furnace of the sun and other hot stars, the electrons, protons, neutrons and atoms present must be endowed with high average velocities owing to thermal agitation. It is thus to be expected that the processes both of disintegration and aggregation of nuclei, such as are observed in the laboratory, should be operative on a vast scale for all nuclei, and that a kind of equilibrium should be set up between those two opposing agencies of dissociation and association for each type of atomic nucleus. It is well known that the abundance of the elements in our earth's crust varies very widely. Some elements like iron, nickel and oxygen are abundant, whilst others like lithium, platinum and gold are relatively rare. The information to be gained in our laboratories on the efficiency of various types of agencies in transforming atoms may help us to throw light on the reason for the

relative abundance of different elements in our earth, and thus in the sun from which our earth is believed to be derived.

In conclusion, let me say a word on the prospects of obtaining further knowledge of transmutation in the near future. While it is dangerous to prophesy in science, the main lines of attack are sufficiently clear to look at any rate a short distance ahead. In the first place, plans are being matured in many laboratories throughout the world to obtain much higher voltages and faster particles of all kinds for a further intensive attack on this problem. Van de Graaff has devised a new type of electrostatic generator whereby he hopes soon to obtain a steady potential of ten million volts with which to accelerate atoms in a discharge tube. The magnitude of this voltage may be gauged from the fact that it will give a miniature lightning flash more than fifty feet long. Lawrence, by a special method of multiple acceleration, hopes to obtain projectiles with energies greater even than those carried by the α-particles from radium. Observations are also being made on the transformation effects of the extremely energetic particles present in the cosmic rays which pass through our atmosphere. Many of these have an energy of one hundred million volts, while some are believed to have an energy of more than one thousand million volts. No doubt also the possibilities of transmutation by high frequency radiation of the x-ray type will be carefully examined. There seems to be little doubt that by the use of still faster particles of different kinds and possibly by other agencies, we may hope in the next few years to observe the transmutation of some of the heavier elements on a small scale. As we have seen, a successful method of attack on the general problem has now been opened up, and extraordinarily powerful yet delicate devices are available for studying the diverse effects which may arise during the transformations.

As one whose scientific life has been largely devoted to investigations on the structure and transformation of the atom, I watch with much interest and enthusiasm the development of these beautiful experiments to add to our knowledge of the constitution of nuclei. No one can be certain what strange particles or unexpected phenomena may not appear. I know of no more enthralling adventure of the human mind than this voyage of discovery into the almost unexplored world of the atomic nucleus.

APES, MEN AND TEETH

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TEETH tell the tale of human evolution better than any other bodily structure. No, I have not forgotten brains. But we do not understand the evolution of the human brain. Our brains are apparently much too big for the use we make of them. Certainly, neither we nor our immediate or remote ancestors have taken thought sufficiently to add many cubic centimeters to our cranial capacities. Yet here we are—all decked out in our 7¼ hats—and no place to go. We have less reason to be proud of our brains than to be ashamed of our teeth.

Teeth seem to be a distasteful subject for popular consideration. They are unpleasantly reminiscent of the apprehensive minutes spent in the dental waiting room with the futile distraction of back numbers of cheery periodicals—and other far worse experiences Yet our teeth have had an illustrious past; they have a serviceable present, and with due conservation they will continue to perform an indispensable function in the future of man. But if the human dentition breaks down, it will carry with it in its fall the human species.

You must know the history of the teeth in order to appreciate them, and because this history epitomizes human evolution. The control of future human evolution is now in man's own hands—or perhaps rather in his teeth.

SHORT HISTORY OF TEETH

Teeth are the most nearly imperishable relics of the vertebrate body. If an animal's teeth last until death, they will continue to defy the destructive action of time and the elements—sometimes for millions of years. After death the soft parts of the animal body decay rapidly. The bones are much tougher. But bones are frequently crushed into dust or dissolved by the action of chemicals in the earth. Furthermore, they are often and perhaps usually devoured by carnivorous animals for which they are a *bonne bouche*. But teeth are singularly unpalatable and indigestible morsels. No animal eats them or, if it does, manages to digest them. They remain as monuments of extinct species. This is peculiarly fortunate for the student of evolution, since the teeth are not only the most durable, but also the most instructive of bodily parts.

Teeth are derived from scales—as are also nails and hair. In the shark—one of the most primitive of existing vertebrates—the skeleton is still cartilaginous rather than bony, and the teeth are rows of modified and sharp-pointed scales which succeed each other in series, a fresh row rising up to take the place of its worn-out predecessor. But in some sharks the teeth form a sort of continuous and blunt pavement. The kind of teeth which grow up in successive rows are laterally compressed cones with cutting edges, at the base of which two or more smaller cones may be developed. But in one existing and several extinct groups the hinder teeth have already developed blunt crowns for crushing the food. Sharks are next to the oldest fishes known, and first appear in the Devonian period—far back in the Primary era (350 million years ago, according to most recent radioactive scales of time).

It is hardly necessary to state that teeth are primarily for the purpose of grasping food and biting it off, and secondarily for the purpose of chopping or crushing it up into pieces small enough to be swallowed and digested.

The mouth of an animal naturally is situated at the head end, in which the sense organs and nervous system are concentrated. This end goes first and the intake of food is conveniently at the prow or snout and the outgo of waste products at the stern or tail. A primitive vertebrate needs some sort of snout or projection of the facial skeleton to carry the smelling and biting apparatus well in advance of the visual organs. It is desirable to get one's teeth and even one's nose into his food, if one is a grazing animal—but never the eyes. So the snout is an ancient vertebrate inheritance—rendered obsolete only by hand-feeding in the Primates and man. A long snout generally goes with a shortage of brains, over-emphasis of the sense of smell in brain area and a generally inferior zoological position.

In the Devonian period, 350 millions of years ago or more, there also appear progressive bony fishes with teeth sharply differentiated in form from scales, covering the margins and inner sides of the jaws and the roof of the mouth. The marginal teeth are pointed with complexly infolded bases. These teeth are now often set in sockets.

The most primitive teeth, such as the shark possesses, are of a predatory grasping type. In later and more evolved fishes the jaws become adapted for various purposes—nibbling, grinding, sucking, and the like.

The first land-living, air-breathing vertebrates seem to have developed from the lungfishes of the Middle Devonian. This group of lungfishes is represented to-day by a few degenerate survivors in Africa, Australia and South America, some of which come up to the surface to take an occasional gulp of air, while others breathe exclusively through the lungs during the dry season, being immured in a sort of cocoon in the mud. Thus the first breathing may have been done in a mud hut. The teeth are the same as before—with elaborately infolded bases.

Apparently as far back as the middle of the Devonian period some of these lungfishes got to living permanently on land, breathing continuously by means of lungs instead of gills, and crawling around some way or other by using their paired pectoral and pelvic fins as paddles, props, and eventually as limbs. Just how the fins developed into limbs is still a mystery—but they did. The teeth changed very little. So the amphibians, the first four-footed, air-breathing vertebrates, came into being. They still had strong predatory jaws with sharp pointed teeth—capable, however, of deploying into various specializations of types for crushing shelled invertebrates, herbivorous diet, fish-catching, et cetera.

The first reptiles developed from amphibians in the Carboniferous period, principally by getting rid of the tadpole stage, characteristic of the latter. For the eggs of amphibians are laid in the water, and the young at first breathe through gills and only in adult stages become air-breathing and land-dwelling. Reptiles, on the contrary, lay their eggs on land, and the young are lung-breathers from birth. Reptiles must have come upon the stage some 200 millions of years ago.

In some of the early but progressive forms the teeth have begun to lose their infolded bases and have tended to become simple peg-like cones, embedded in sockets, and all alike—fore and aft. The primitive reptile forms seem to have been more or less predatory and carnivorous. The process of differentiation of teeth into different forms according to their location in the jaws had already begun. Obviously, the teeth at the front end of the jaws should be shaped for cutting and piercing, because that is the end of the jaws with which bites must be taken. These anterior teeth sweep through a greater arc and with a greater velocity than the back teeth. At the corners of the jaw the primitive reptilian peg-like form tends to be preserved in

the canines or tusks—used for piercing and holding, and the front teeth may be modified into chisel forms for cutting—the incisors. The farther back in the jaw the teeth are, the greater the leverage of the jaws and the more force may be brought to bear upon the teeth. These, however, move through a smaller arc than the front teeth. Consequently, they are better adapted for crushing and grinding. If you have lost your back teeth, you realize that chewing with the front teeth is both public and ineffective.

Some of these early reptiles began to be suspiciously like mammals. Instead of going on their bellies, or waddling with their knees and elbows bent and thrust out sideways from the body, they managed to get their fore and hind legs well under their bodies, straightened them a bit, perhaps, and really were progressive. They "got going." They had two sets of teeth—not simultaneously, but successively—even as you and I. One of these was a milk set to carry on with while their jaws were growing, the other a "permanent" set which was supposed to last them the rest of their lives—and probably did, contrary to our common experience. The mammal-like reptiles did not content themselves with monotonous rows of peg teeth, but boasted incisors, canines, premolars and molars—in fact, all the recognized and respectable varieties. If you do not believe this, go to South Africa and dig up a Therapsid from the Triassic beds. No doubt any one there can direct you.

From these advanced and progressive mammal-like reptiles—not slimly, crawling marsh denizens, but dry land-dwellers—the mammals evolved in the Triassic period. Throughout the Age of Reptiles (say from 200,000,000 B. C. to 60,000,000 B. C.—a few millions more or less, if you like) mammals apparently remained wretched and insignificant little creatures, of small importance in the zoological world. They were lying low. Probably the earliest of them were insectivorous (insect-eating). They seem to have had four incisors, one canine, five premolars and six molars, on each side above and below. Probably the molar teeth had already begun to take on a three-cusped triangular form—suitable for crushing bugs.

At any rate, in some fashion or other, the molar teeth became broadened for grinding and developed in the upper jaw three cones or cusps and in the lower three cusps and a crushing basin, so that the upper and lower teeth efficiently interlocked for chewing purposes.[1]

Because they were puny and crafty—or modest and self-effacing—these small insectivorous mammals skulked in the underbrush and slunk out of the way of the giant reptiles of the Secondary Era, biding their time until they should develop into the masters of the world. This period of incipient and suppressed mammals seems to have lasted for about 140 million years—until 60 millions of years ago, according to radioactive time scales. During this long interval the tiny mammals developed in various directions in bodily form and tooth adaptations, but the stock which gave rise to the Primates (lemurs, tarsiers, monkeys, apes and man) was arboreal. It is represented to-day by the primitive tree-shrews.

Here I must descant upon the advantages of arboreal life for a small mammal. The forest nursery offers a comparatively safe existence. Large predatory carnivores find it unprofitable to chase the small animal up trees. The

[1] This may seem unimportant to you, but just stop to consider. If you are unable to chew your food properly, you must either subsist on soft fodder and "slops" or swallow large gobbets, thereby putting a huge task upon your digestive apparatus. Simultaneous digestion and cerebration are incompatible. If you spend all your time digesting, you will never learn to think.

agile climber is secure, providing he does not fall out of the tree. He can eat leaves, shoots, nuts, fruits, birds' eggs and insects and birds, if he can catch them. Nests may be built and the young comfortably reared. But more than this, arboreal life puts a premium on sight. Smell is the most important sense for a small ground animal, both for finding food and for avoiding enemies. The snout is both an olfactory and a tactile organ. The little animal "noses its way" through life. But supposing he climbs a tree! Smelling becomes relatively unimportant, acuity of hearing is not as essential as on the ground. But the arboreal animal must "keep its eyes peeled"!

The insect-eating pre-Primates had long snouts with moist muzzles, eyes laterally directed, five digits on the hands and feet, two incisors, one canine, four premolars and three molars on each side, above and below. They were small quadruped climbers, long of tails and short of brains, with dietetic habits which extended to fruits, leaves, shoots and nuts as well as insects.

From these humble little brutes sprung the Primates, at the beginning of the Tertiary Epoch, 60 millions of years ago. At first there was nothing higher than lemurs—small arboreal cat-like animals whose descendants may still be seen in the forest of Madagascar, Africa and the Indo-Malayan region (or in the better zoological gardens). The lemur, however, represents a considerable advance over the insectivore. Primates are characteristically equipped with five digits on hands and feet which are provided with flat nails instead of claws and the thumbs and great toes of which may be opposed to the outer digits in grasping boughs. This opposability of thumbs and great toes is the secret of the manual dexterity of Primates and culminates in the mechanical supremacy of man, although man's foot has ceased to be a grasping organ.

Lemurs are omnivorous. Pause and contemplate the advantages of being able to eat almost anything. (If you live in a boarding-house, you know this already.) In the struggle for existence, it often means survival. Even in human society a good digestion and an ability to eat all kinds of food is better than riches or even intelligence. The modern lemurs have lower incisor teeth which lean forward and are supposed to be used for combing their fur; they have three premolars and three molars. Apparently, when the teeth become differentiated and the diet is generalized, fewer teeth avail the animal. The earliest lemuroids are found in the Eocene in North America—the first of the Tertiary geological deposits. Now we have to look for them in out-of-the-way tropical forests in the Old World.

The tarsioids are little pop-eyed cousins of the lemurs—geologically about as old and in structure almost as primitive. But they were more progressive and upstanding, or rather upsitting. In the first place, they hopped from bough to bough, instead of running on all fours along the branches. That gave them a free pair of hands to explore, to scratch, and wherewith to feed themselves and to pluck of fruits of the tree of knowledge. (The tarsiers were, of course, arboreal. The modern descendants are found in the forests of the Indo-Malayan archipelago.) The number and kinds of their teeth are the same as in the lemurs, but the snout is shortened, the brain case is relatively large and the orbits of the eye are directed forward, making the fields of sight overlap so that stereoscopic vision results. These tarsiers went right on eating everything they could find in the trees and remained unspecialized in teeth, but began to specialize in eyesight, in tactile sense, perhaps even in common sense. At any rate, the habit of hand-feeding, the shorter snout, the better vision and the larger brain are all inextricably evolved in the organ-

ism of the little omnivorous animal. The tarsier is the infant prodigy of the Primates.

Out of some primitive but progressive tarsioid of the Eocene period (some 55 millions of years ago) there evolved the stocks which have led to the higher Primates (monkeys, apes and man). We may profitably pause to consider very briefly a tiny fossil monkey, named Parapithecus, found in the Lower Oligocene of Egypt (dated about 35 million years ago). This little animal, represented only by a lower jaw and teeth, stands, in the opinion of Professor W. K. Gregory, at or very near the line of descent leading to the anthropoid apes and eventually to man. It may be regarded as a generalized super-tarsioid, or pre-monkey of the Old World. It already has the human dental formula: two incisors, one canine, two premolars and three molars, on each side and in both jaws. It has small and unspecialized canine teeth and blunt premolars and molars which would seem to preclude carnivorous or flesh-eating habits. Its incisors, leaning gently forward, and its low-cusped cheek teeth seem to point to a mixed diet—perhaps insects, fruits, birds' eggs and small reptiles. In fact, it ate hors d'oeuvres, omelette, entrée and dessert. From such an early form the Old World monkeys diverged, specializing in different directions, but in general tending to display an elongation of the canines, useful in fighting and in piercing the rinds of tough fruits, and a pairing of the molar cusps, four in each tooth, in groups of two. These molar cusps have now become quadrate, having lost the earlier triangular form.[2]

We need only two more steps in dental evolution to bring us up to man, but we have to "step high." The first of these is taken in the most ancient and primitive fossil anthropoid ape—Propliopithecus—again a find of the Lower Oligocene of Egypt. This early anthropoid with the jaw-breaking name may have lived some 35 millions of years ago. Nothing survives of this little ape except a lower jaw with its teeth, but its lower canines were smaller than those of recent gibbons, its snout shorter and its molar teeth less specialized in form. Propliopithecus was no bigger than a human suckling; he was a proto-ape with a small brain and no chin; but that little jaw and those generalized teeth mark out the pattern of development which eventually lead to man. Propliopithecus—not Tut-ankh-Amen—is Egypt's crowning glory.

The final step preceding the arrival at the human plane of dental and general body development may be studied in the remains of the great Dryopithecus family of generalized giant apes, from which it seems most likely that the gorilla, the chimpanzee and man eventually developed as separate modern descendants. Remains of the Dryopithecus family are found in North Africa, in Europe and in the Siwalik Hills of India, at the foot of the Himalayas. This family was flourishing in mid-Miocene times—roughly 14 million years ago. The stems leading to the modern apes of Asia—the gibbon and the orang-utan—had previously diverged from the common anthropoid-human trunk. Jaws of members of the Dryopithecus family clearly show the ancestral pattern of the molar teeth which is found in the chimpanzee, the gorilla and man. These apes had the same number and kinds of teeth as you have, but the lower canines were large and pointed with erect tips. The hinder premolars were bicuspid as yours are. The lower molars were arranged with five main cusps, three on the outside, two on the inside, and sometimes a smaller hinder cusp in the middle. This is Professor Gregory's "Dryopithecus pattern," which is preserved in the molar teeth of most fossil men, of many recent savages and in your first

[2] But four-course dinners do not necessarily demand four-cusped teeth.

and second lower molars and in mine—if we still have them and are not too degenerate.

We must conceive these generalized precursors of man and the African great apes as large Primates with projecting jaws and only moderately large brains, who progressed through the trees by brachiating—swinging by the arms; who had prehensile feet as well as grasping hands. They were probably not specialized in the tremendous elongation of the arms that we observe in the gorilla, the chimpanzee and the orang-utan of to-day—animals which have displayed the conservatism which limits evolutionary development and which has induced them to remain tree-dwellers, or half-hearted quadrupedal ground-dwellers like the gorilla, long after their size, strength, intelligence and dietary requirements demanded a fuller and richer existence as erect, terrestrial bipeds. Note that man, like Zaccheus, owes his importance to the fact that, having climbed a tree, he straightway came down.

One of these Dryopithecus lines had the supreme gift of super-anthropoid intelligence and initiative. Its members took to the ground and eventually stood up on their hind legs, having developed stable supporting feet from the ancient Primate grasping organs. Their arms and hands were set free for prehension. They began to use weapons and tools—a step which initiated human culture and took the strain off their jaws and teeth, previously employed for offensive and defensive as well as masticatory purposes. Gradually the snout shrank back, and this recession seems to have been accompanied by an overgrowth of the brain. These are associated evolutionary phenomena, but the one did not necessarily cause the other.

Some pessimistic paleontologists (by which I mean the ponderous pundits who study the remains of extinct animals) think that the line of anthropoids which came down from the trees and developed into man either fell out of the branches or was pushed out by a deforestation of the area which it inhabited. This is a very controversial subject, and I must place myself definitely "on the side of the angels." I do not give man full credit for his evolution from lower forms, but I am convinced that it was the ability to grasp an opportunity and the gift of initiative supreme in this humanoid stock which urged it forward on the path of humanity. If this be orthogenesis, Lamarckianism or any other sort of biological treason—make the most of it!

Now I am by no means contesting that man developed from a shark purely through shifting the form and function of his teeth—or that he ate himself up to a human status. Nothing that a Primate does or does not do with his teeth makes him a man or a gorilla. But I can determine whether you are a man or a gorilla as quickly and correctly by looking at your teeth as by observing any other feature of your anatomy or any item of your behavior. In other words, teeth tell the story of human relationship, but they do not explain why we have this possibly disreputable ancestry. It is there, whether we admit it or not. However distasteful and disconcerting these ancestral skeletons may be, they are there in the family closet![8]

The Teeth of Fossil Man

But we must pursue the rise and decline of the human dentition through fossil man and down to modern and degenerate times. The earliest representative of the humanoid stock of which we possess remains is the *Pithecanthropus erectus* of Java—still nearly halfway down to the ape in brain size, but with a thigh bone which indicates

[8] Throughout this section I have levied a very heavy toll upon Professor W. K. Gregory's work, "The Origin and Evolution of the Human Dentition," *The Journal of Dental Research*, 1920, 1921.

that he strode erect through the forests, even as you and I over the pavements. He belongs back in the beginning of the Pleistocene—nearly one million years ago. What kind of teeth had Pithecanthropus? We have only a couple of molars to go by. They are large and with strongly divergent roots and fangs, but they already show some degeneration and cusp reduction which is essentially human and not anthropoid, although one of them recalls to Professor Gregory the fine old Dryopithecus pattern.

Somewhat more advanced in brain development than Pithecanthropus are the recently discovered men of the Sinanthropus type, found in deposits of the Lower Pleistocene near Peking, and dating back probably to the early quarter of that period—750,000 years ago. These early Pekinese had jaws with incipient chins—a jump ahead of the chimpanzee, bath-tub shaped jaw. The canines were not projecting as in anthropoid apes. The molar teeth were low-crowned like those of a chimpanzee—the molar cusps in the lower jaw being five in number like the ancient Dryopithecus pattern. Curiously, the front halves of the molar teeth are ultra-human or almost degenerate, and the back halves are ape-like. But the queerest feature of these ancient Chinese teeth is found in the pulp cavities of the molars. The crown of a tooth is the part above the gum; the roots are sunken into the alveolar bony sockets of the jaw. Through the roots run fine canals into a central cavity which is filled with pulp—blood-vessels and nerves. The walls of the pulp cavities are of dentine or cement, and the outer layer of the crown of the tooth is hard enamel. In modern man and the apes the pulp cavities of the molar teeth are small and do not extend down below the crowns. But in Sinanthropus, and in the later Heidelberg and Neanderthaloid races, the pulp cavities are enlarged and the body of the tooth with the pulp cavity is prolonged downward below the alveolar borders of the jaw at the expense of the roots, which are short.

This specialization is called taurodontism, because it occurs in animals which chew the cud. It is exactly the opposite of the cynodont or dog-tooth condition found in the anthropoid apes and in modern man. Must we infer that the ancient precursor in China was a ruminant? I think not. He was probably omnivorous and knew neither rice nor birds' nest soup. But the importance of this specialization is that it seems to remove Sinanthropus, and the other ancient types which show it, from the direct line of descent which leads to modern man. The premature herbivore-like specialization of molar teeth is peculiar to Sinanthropus and the low-browed Heidelbergers and Neanderthaloids.

I do not propose in this article to pick over the teeth of every fossil type of man, but merely to jab at a few suspicious and tender spots—marking significant findings—as your dentist when he is looking for cavities. In general, the successively higher types of fossil man show a decrease and recession of the jaws, a gradual thrusting forth of the chin, and the change of the palate shape from a long, narrow U type found in the apes and associated with snoutiness to a parabolic type in which the dental arches spread from front to back, no doubt in correlation with the increasing breadth of the brain case to which the jaws are hafted. The teeth themselves gradually become smaller, the molars wider and shorter, and the number of cusps tends toward reduction in both upper and lower jaws. The molar teeth also get smaller going from the first back to the third or wisdom tooth, whereas in some fossil types and anthropoid apes they increase in size from front to rear.

Probably the most striking change from the anthropoid ape type to human

type has to do with the reduction of the great projecting tusk-like canines, which in apes interlock, stop skidding of the jaws, and effectually prevent the lateral and rotary movements of the jaws which are characteristic of primitive man, but seem to be retained in effete civilization principally among gum-chewing stenographers and tobacco-quid-masticating rustics. It is here that we run upon an unsuspected snag in navigating the little known stream of human dental evolution. For the Piltdown skull, familiarly known as Eoanthropus or the Dawn Lady, unexpectedly turned up in a Lower Pleistocene deposit with a beautifully formed brain case, complete with high brow and capacious brain, but with a chinless jaw like that of a chimpanzee and a projecting tusk of a canine which belongs in that jaw. The molar teeth of this anomalous and contrary female were low, narrow and long—highly reminiscent of the chimpanzee—and possessing in the mandible the ancestral five-cusped Dryopithecus pattern. But in some important respects they approximate a human type.

Confronted by this highly contradictory combination of ape-like jaw and teeth and wholly human brain case, some anatomical skeptics have attempted to cut the Gordian knot by attributing the advanced brain case to some pre-English Boadicea and the jaw to her pet chimpanzee. However, this view fails to account for the lady's missing mandible and the ape's lost brain case, and is based upon a mistaken idea that the course of human evolution was symmetrical in all parts—that all types advanced harmoniously from the ape to the human form. We know now that human evolution was a multiple and asymmetrical process, involving many different types struggling upward toward humanity, some precocious in one part of the anatomy and laggard in another part, while others displayed reverse combinations in the association of prematurely human and retardedly anthropoidal parts. Thus Pithecanthropus got his human gait and legs before he attained a human size of brain, and Sinanthropus was scarcely human in brain size but prematurely specialized on the human side in certain features of dentition. So we must accept the Piltdown lady as a mysterious compromise who may be in our own ancestral line in spite of her chinless chimpanzee-like jaw and projecting canines The pulp cavities of her molar teeth, like ours and those of our anthropoid cousins, were not enlarged. Her canines were beginning to shift from the sides of the jaws to the front and she may have been able to chew from the outside in toward the middle, as all good primitive men and women chew. This is a sort of motion which can not be managed by the apes on account of their interlocking canines.

It is sad to relate that fossil men of glacial times already show clear hints of certain dental degeneration. The Ehringsdorf jaw, which may be 500,000 years old or perhaps only 250,000 years, shows definite decrease in size and degeneration of the cusps of the third molar or wisdom tooth. Some of the Neanderthalers have upper third molars with only three cusps instead of the primitive four.

However, the most shocking person in the array of fossil ancestors is the Rhodesian man, dug up in a zinc mine of South Central Africa and equipped with the most gorilla-like beetling bony brow-ridges, the longest face, the largest palate and the worst teeth of antiquity. Not only has this fellow reduced and degenerate wisdom teeth, but nearly all his teeth have been attacked by caries or decay; there were abscesses at the roots of many, and the "danger-line" was riddled with pyorrhea—a septic condition of the gums which leads to eating away of the bony tooth sockets, loosening of the teeth, the entrance of all sorts

of poisons into the system through the absorption of pus, to say nothing of "pink toothbrush." This Rhodesian man had an abscessed condition of the mastoid region, which had drained right out through the bone. In fact, he sorely needed a dentist.

THE DECLINE OF HUMAN DENTITION

Savage or primitive types of modern forms of man have smaller teeth than the fossil men, but their palates are broad and capacious, their incisor teeth meet edge-to-edge in most cases; their molars have four good cusps in the upper jaw and five in the lower, and the third molars are usually not much reduced and not greatly retarded in eruption. The good old Dryopithecus pattern of molar teeth evinces their illustrious ancestry.

Civilized man has smaller teeth and frequently a small contracted palate. Usually the lower incisor teeth bite behind the upper incisors so that the latter overhang, giving rise to an "overbite" and often, when they protrude, a "buck-toothed" effect. But, worse than this, the lower and upper teeth frequently fail to erupt in their proper positions, so that they do not engage efficiently and permit proper mastication of food. This malformation of the jaws is called "malocclusion" and comes in a variety of forms. Its cause is complicated and obscure, but seems to lie in hereditary evolutionary tendencies of a degenerative nature, possibly induced to some extent by lack of proper healthy exercising of the jaws and teeth—a consequence of the excessive use of soft cooked foods.

Malocclusion is principally a phenomenon of modern civilization and it is increasing most alarmingly. It must be combatted. The dental specialists who are striving against this retrogressive tendency in human evolution are called orthodontists. Theirs is the difficult task of finding out the cause of this malformation and eradicating its disastrous effects. They are most skilled to warp and move and straighten teeth so as to bring them back into efficiency and symmetry, but as yet they do not know how to keep them there, just where the teeth should be moved and why they erupt out of position in the first instance.

The other two great manifestations of the decline in the human dentition are caries or decay and pyorrhea. Most savages show few or no cavities in their teeth. They may wear their teeth down by eating gritty food, until the pulp cavities are exposed and the tooth dies and decays, but the primary caries—the eating away of the tooth by bacteriological or other destructive agencies in the mouth—is extremely rare—at least until the savage comes into contact with civilization, missionaries, canned foods, groceries and candy. But nine out of ten school children in the United States have decayed teeth, and civilized adults probably show nearly 100 per cent. of mouths which contain one or more carious teeth. This decay of the teeth means the introduction into the system of poisons which cause rheumatism and a host of major ailments which may follow this primary infection. Yet no one to-day knows the cause of dental caries. It may be partially a matter of diet and particularly caused by diets lacking in one or more of the necessary vitamins. But it is by no means exclusively due to diet, since primitive peoples living under a wide range of dietetic conditions usually manifest few if any ravages of this terrible disease.

Pyorrhea is a septic condition of the gums, which is even more obscure in origin and far more difficult to treat than simple dental caries. The bacteriological agencies present are to some extent known, but the cause is not the lack of use of a toothbrush, nor is the remedy to be found in frequent scrubbings

with this or that allegedly antiseptic toothpaste. Of course brushing the teeth is like buttering the baby's heel, it can not do any harm and it may do some good. This is always providing that the toothpaste used is not abrasive nor of such a nature as to attack the enamel. Of course the teeth should be kept clean, just as the feet should be kept clean. And the mouth and teeth which guard the digestive tract are much more vulnerable to germinal incursions than is the skin

The facts that we must face are, in brief, that human teeth and the human mouth have become, possibly under the influence of civilization, the foci of infections that undermine the entire bodily health of the species and that degenerative tendencies in evolution have manifested themselves in modern man to such an extent that our jaws are too small for the teeth which they are supposed to accommodate, and that, as a consequence, these teeth erupt so irregularly that their functional efficiency is often entirely or nearly destroyed

How to Stop Dental Degeneration

In my opinion there is one and only one course of action which will check the increase of dental disease and degeneration which may ultimately cause the extinction of the human species This is to elevate the dental profession to a plane upon which it can command the services of our best research minds to study the causes and seek for the cures of these dental evils. Such an improvement of the quality of the dental profession is an indispensable prerequisite for the attacking of these tremendous pathological and evolutionary problems. No effective measures of public education in care of the teeth can be taken until dental practitioners cease to be tinkers and learn to be scientists. In making such a statement I by no means wish to belittle the tremendous progress in the field of dentistry which has already been made.

As a matter of fact, if I were asked in what occupations the United States indubitably leads the world, I should reply without hesitation "Dentistry and plumbing." American dentists have reached a pitch of mechanical skill which is equal to that of American surgeons. But carpentry is not enough. Stopping teeth does not stop tooth decay. In the dental profession to-day are many brilliant scientific minds and many practitioners of consummate skill whose aims are humanitarian rather than pecuniary, but there are too few of such men and they have been insufficiently trained.

The dental profession has been for too long a time a neglected and disowned orphan child of medicine and surgery While millions have been lavished upon medical schools and hospitals, and upon medical and surgical research, almost nothing has been allotted for these purposes to dentistry. Our schools of dentistry have been forced to struggle along without endowments; their teaching staffs have consisted almost entirely of devoted but unpaid men who give part of their time to teaching, but have to make their living in practise.

The prerequisites for admission to dental schools have not been sufficiently high In the past many schools have admitted high-school graduates and students with only one or two years of college preparation. This low standard of admission implies a supply of inferiorily educated men and a commercialized technical course, rather than the broad background of general education essential to the rigorous training of a professional school of medicine. As a result there has been very little scientific research in the dental school and what has been carried on has been principally commercial in its aim. The faculties of dental schools recognize these shortcomings and are striving to raise their

standards and to transform dentistry from a trade to a profession, from a craft to a science But they can not succeed in any large measure until the public and the philanthropic foundations, and especially the medical profession itself, recognize the essential parity of dentistry with other branches of medical science

I am well acquainted with only one dental school—that connected with an old and famous New England university. Like every other dental school, it has been regarded as a yellow dog trailing at the heels of the medical school It has been slighted in endowment, in gifts for research, and generally neglected and half starved Yet this dental school includes in its faculty some of the most enlightened, altruistic and scientifically minded teachers and research workers with whom I have been privileged to come into contact It was the first university dental school in the world, it was the first to lengthen its academic year to nine months; the first to require written examinations; the first to demand graduation from a high school as an entrance requirement; among the first to increase that requirement to two years of college

This institution is now seeking an endowment which is absolutely necessary for its proper development. Let us not attempt to evade the issue Either we must spend the necessary sums to give dental research and dental practise their proper status in the medical profession, or we must spend vastly larger amounts upon dental tinkers, whose unpleasant duty it is to lean over the dental chairs in which we sit, gaze upon the shocking vista of human degeneration which our open mouths present, and attempt the hopeless task of stopping decay and sepsis. I firmly believe that the health of humanity is at stake, and that, unless steps are taken to discover preventives of tooth infection and correctives of dental deformation, the course of human evolution will lead downward to extinction.

THE RÔLE OF BACTERIA IN THE CYCLE OF LIFE IN THE SEA[1]

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THE sea harbors an extensive population of bacteria, varying greatly in numbers and in the variety of their activities This variation depends, in the case of the sea-water, on the distance from shore, depth of water, season of year, abundance of plankton and uniformity of mixing of the water, and in the case of the sea bottom, upon the nature of the bottom material, depth from the surface of the sediment, etc These bacteria take part in a number of processes which are of considerable importance in the life of the plant and animal populations of the sea, namely, in the decomposition of plant and animal residues, in the transformation of their nitrogen to such an available form as ammonia and of their carbon to carbon dioxide, in the formation of nitrate as well as the reduction of nitrate, in the oxidation of sulfur and the reduction of sulfate, in the fixation of nitrogen, in the direct and indirect precipitation of calcium and iron, in the formation of organic matter or humus in the sea bottom and in the decomposition of this humus. To what extent these processes are absolutely essential in the growth of plant and animal life in the sea still remains to be determined.

The study of bacteria in the sea includes a series of problems in bacteriology and in biochemistry which are to be coordinated with other branches of oceanography, in order to establish the rôle of the bacteria in the marine processes. In most instances information on marine bacteriology has been gathered by individual investigators during short periods, using material obtained from few localities; less often the work is the result of an expedition, where limited facilities were offered for a detailed study of bacterial life and of bacterial processes under the natural conditions prevailing in the sea. Most of these investigations had a specific purpose of demonstrating either the presence or absence of certain bacteria in the sea, or of organisms capable of bringing about processes which are known to be of importance to marine life Attempts to correlate the occurrence of a certain organism with an important marine process frequently led to generalizations which were later found to be totally unjustified.

If any phase of biology needs continuous study, it is that of bacteriology, because one deals here with living organisms, rather than with dead specimens, and one must study physiological processes rather than morphological structure. One can not bottle up some sea-water for 6 weeks or even days, then bring it to the laboratory and expect that the numbers and types of bacteria will have remained the same as under the natural conditions of the sea. One can not preserve bacteria, as one does animals or plants, then identify them, as an opportunity arises, since in most cases the bacteria are identified not by their appearance but by their activities.

The fact that a certain bacterium is active in a specific transformation in the laboratory is no proof as yet that it will be responsible for the same reaction in the sea. Samples of sea-water or of bot-

[1] Contribution No. 23 of the Woods Hole Oceanographic Institution and Journal Series paper of the New Jersey Agricultural Experiment Station, Department of Soil Microbiology.

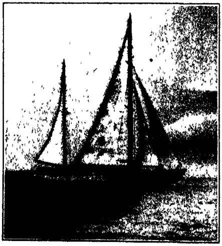
SAMPLING TUBE
FOR COLLECTING, AT DIFFERENT DEPTHS, SAMPLES OF WATER UNDER STERILE CONDITIONS

tom material removed from their environment and brought into the laboratory may give, within a very short period of time, frequently within a few hours, a bacterial population which is quite different quantitatively from the corresponding population in the sea itself; a number of factors may be responsible for this change.

In the case of the bacterial population of the sea, as in the case of soil bacteria or bacteria in inland waters and in sewage, one deals with mixed populations and not with pure cultures. It is not merely sufficient to isolate an organism, cultivate it and determine what it does in pure culture; it is far more important to determine what it does in its natural substrate and how these activities dovetail with the activities of other bacteria, as well as with the whole complex mass of higher plants and animals

In order to illustrate the possible confusion that may arise from the investigation of a single bacterial process in the sea, it is sufficient to call attention to the study of the rôle of bacteria capable of reducing nitrate in certain important marine processes The hypothesis of Drew concerning the precipitation of $CaCO_3$ in the tropics and that of Brandt concerning the insufficient plankton development in tropical seas, as compared with that of temperate and arctic regions, were based largely upon this one specific bacterial process. Not only was considerable importance attached to it, disregarding thereby numerous other chemical and bacteriological processes involved, but an attempt was even made to set up highly generalized theories concerning the whole system of metabolism in the sea on the basis of this process

Drew has shown in 1913 that, in a sea-water medium containing nitrates and calcium salts of organic acids, precipitation of calcium carbonate takes place This reaction was found to be a result of the reduction of nitrate by certain bacteria, which use the organic acid radicle as a source of energy. On the basis of this experiment, the theory



THE LABORATORY BOAT *ATLANTIS*
LEAVING FOR THE GULF OF MAINE FOR A SERIES OF CHEMICAL, BACTERIOLOGICAL AND PLANKTONOGRAPHIC INVESTIGATIONS.

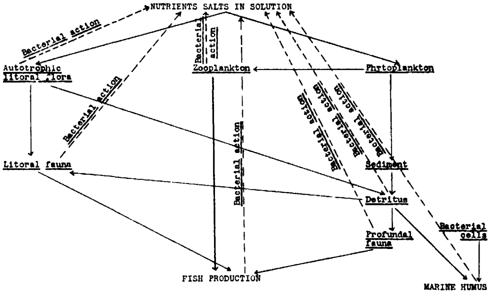


CHART I PLANT, ANIMAL AND BACTERIAL RELATIONSHIPS IN THE SEA

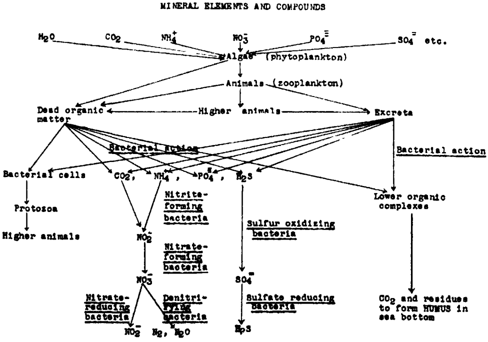
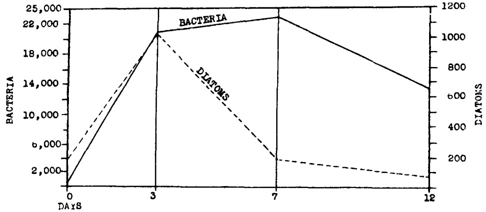


CHART II. RÔLE OF BACTERIA IN THE CYCLE OF LIFE IN THE SEA

was proposed that the precipitation of $CaCO_3$ in the chalk muds in the Bahama region, off the coast of Florida, and probably in other places is due to action of bacteria Even granting that Drew was right in his conclusions, namely, that his experiments proved that precipitation of $CaCO_3$ in the sea may be due to the action of bacteria, he made two purely hypothetical assumptions not based upon any experimental evidence, which would tend to nullify these conclusions, as applied to large regions. These assumptions are that nitrates are produced in the sea in sufficiently large amounts and that sufficient quantities of organic acids are present in sea-water to bring about the dissolution of the calcium and to serve as an energy source to the nitrate-reducing bacteria. The mere fact that an organism can reduce nitrate in an artificial culture medium is no proof that this process forms an important phase of the activities of the organism under natural conditions. A great many pathogenic bacteria are able to reduce nitrate, although this substance does not occur in appreciable quantities in the blood or in other tissues where these bacteria are active.

In criticizing this hypothesis, C. B. Lipman suggested that the sea does not contain a sufficient number of bacteria to bring about such an extensive process. However, the activities of the bacteria are not limited by their numbers but by the amount of available energy, the abundance of nutrients and favorable environmental conditions Lipman concluded that calcium precipitation in large quantities in the sea can be more readily explained by purely physicochemical processes, although he did not deny the possibility that microorganisms may bring about, directly or indirectly, the precipitation of some calcium carbonate. Kellerman and Smith, who upheld Drew's hypothesis, believed that the denitrifying bacteria are specific "calcium bacteria," indicating thereby that the process of calcium precipitation plays the predominant function in the life activities of these organisms. Molish went even a step further and described various new species of bacteria on the basis of their ability to cause the precipitation of calcium. These conceptions are hardly justified, since the reaction of calcium precipitation, even under Drew's experimental conditions, is only secondary in nature and does not form an important phase of the physiology of the bacteria. Further, in addition to various denitrifying bacteria, other organisms, such as urea and sulfate-reducing bacteria, are also able to bring



CHANGES IN NUMBERS OF BACTERIA AND DIATOMS IN SEA-WATER CULTURES, NUMBERS IN 1 CC OF CULTURE.

about the precipitation of calcium. Unfortunately, neither Drew nor those following him seemed to have been familiar with the fundamental work of Nadson on "Bacteria as Geological Agents" published nearly 30 years ago, which tended to illuminate this process.

The second hypothesis based upon the activities of nitrate-reducing bacteria was even more far-reaching in its application. Brandt was among the first to emphasize the important part played by bacteria in the cycle of life in the sea He suggested the following explanation for the relative abundance of plankton in the arctic and temperate regions and its comparative poverty in the tropics In warm regions, the denitrifying bacteria are very active and destroy the nitrates, thus bringing about a nitrogen minimum; in cold regions, where the denitrifying bacteria are not so active the abundance of nitrate permits considerable plankton development This hypothesis has had a considerable influence upon the subsequent development of research on the bacteria of the ocean Assuming that the observations concerning the relative abundance of the plankton in the sea, under different climatic conditions, are correct, the explanation suggested is very much open to criticism, since one would have to establish first that nitrates are formed in the tropical regions as abundantly as in the temperate regions, that bacteria are more active in the tropics and that more energy, in the form of plant excreta or residues, is available in the tropical seas to enable those bacteria to reduce the nitrate. Possibly the more rapid disappearance of the organic residues in the tropical waters, due to the greater activity of the bacteria decomposing the organic matter, may have more to do with this phenomenon than the activities of the denitrifying bacteria. Recent studies by Butkewitsch established the fact that nitrate-reducing bacteria are

CONNECTING SAMPLING TUBE TO LINE

TUBE FOR SAMPLING OF MARINE MUD UNDER STERILE CONDITIONS

also found in cold regions as in the Barents Sea, while investigations carried out at the Woods Hole Oceanographic Institution brought out the fact that the activities of most of the nitrate-reducing bacteria in the sea are limited to the reduction of nitrate to nitrite and not to atmospheric nitrogen

These two illustrations are sufficient to emphasize how certain limited observations on the activities of one group of bacteria isolated from the sea, namely,

PETERSEN GRAB
FOR SAMPLING OF MARINE BOTTOMS.

the denitrifying organisms, can be so magnified as to make them appear as among the most important members of the bacterial population of the sea. One should add here that Brandt's hypothesis was not accepted by Gran and other prominent oceanographers, who demonstrated that the available evidence is either insufficient or even contrary to it

The Cycle of Life in the Sea and Bacterial Activities

A graphic representation of the rôle of bacteria in the cycle of life in the sea is given in Charts I and II. Chart I shows the general relation of the bacterial activities to the interrelationships of plants and animals in the sea and to the various degradation products, while a more detailed analysis of the specific marine processes in which bacteria are chiefly concerned is shown in Chart II.

According to Thienemann, the plankton consists of three groups of organisms. (1) "producers," comprising largely the chlorophyll-bearing diatoms and algae which build up organic substances from the inorganic nutrients dissolved in the water; (2) "consumers," or the animal representatives of the plankton which feed upon the living or dead members of the phytoplankton or their metabolic products; (3) "reducers," comprising the bacteria, which decompose and mineralize the high-molecular compounds formed by the producers and consumers The last two groups are in definite nutritional relations to one another One can easily enlarge upon this idea and include among the consumers also the higher animals, which feed both upon producers and consumers of a lower order; among the reducers one can include not only the bacteria of the plankton but also the bacteria of the sea bottom which take an active part in the destruction of plant and animal residues in the sea, as well as the animal population of the sea. Certain groups of bacteria will also be found among the producers, such as the nitrogen-fixing bacteria; bacteria may also be considered as consumers, since they synthesize bacterial cell substance. One can add a fourth group, namely, "transformers," which comprise those bacteria, like the nitrifying, sulfur-oxidizing, nitrate-reducing and others, which play a most important rôle in the transformation of various elements and compounds, aside from the above three general processes.

The plant population of the sea synthesizes, under proper light conditions, organic substances out of the simple nutrients, namely, the water, CO_2, available nitrogen compounds, soluble phosphates and other inorganic salts. The animals of the sea which are unable to utilize the photosynthetic energy of the sun must obtain their energy and materials necessary for the construction of their body substance from the plants, either directly or indirectly. Some lower animals, such as certain foraminifera, radiolaria, coelenterata and others, actually carry living algae which synthesize organic matter and thus serve for the nutrition of their host. After the death of the numerous plants and animals which inhabit the sea, their bodies as well as their excretion products are decomposed by bacteria living in the water, on the plankton or in the bottom sediments, as shown in the photographs.

Among the most important activities of the bacteria in the sea are the decomposition of plant and animal residues and the transformations of nitrogen. By decomposing the residues of marine plants and animals as well as their waste products, the bacteria return, in a mineralized form, to circulation in the sea, and in the atmosphere those elements from which the diatoms and algae inhabiting the sea synthesize their cell substance, namely, the carbon as carbon dioxide, the nitrogen as ammonia, the phosphorus as phosphate, etc. Without these actions of the bacteria, the sea bottom would soon become covered with a mass of dead plant and animal débris, and the limited supplies of available carbon (CO_2), of available combined nitrogen and of phosphate would soon become transformed into organic forms which are unavailable for growth of marine plants; this would result in cessation of plant life in the sea. In the process of decomposition of the residues, the bacteria themselves synthesize considerable cell substance, which may actually serve as food for various invertebrate animals and thus form a constituent part of the plankton of the sea.

DECOMPOSITION OF *ULVA LACTUCA*
BY FUNGI, FOLLOWED BY ATTACK OF THE FUNGUS MYCELIUM BY BACTERIA

Bacteria may also live symbiotically with various marine plants and animals. Among these symbiotic relationships, that of the green algae and the nitrogen-fixing bacteria has been suggested. In recent investigations carried out at the Woods Hole Oceanographic Institution, a close parallelism was found in the water and in the plankton between the abundance of diatoms and other plant and animal constituents and the numbers of bacteria. When the diatoms die, as shown by the rapid diminution in numbers, the bacteria still continue to develop at the expense of the diatom cells. This suggests the probability that the bacteria live in the free water only to a limited extent, but that they are largely associated with the plant and animal forms of the plankton, attacking

their excretion products, as well as the dead bodies.

Methods of Study of Marine Bacteria

Studies of marine bacteria have four distinct ends in view: (1) determination of the relative abundance of bacteria in the sea-water and in the sea-bottom material; (2) detection of the specific nature of the bacterial population, namely, the types of organisms that make up this population under the various conditions; (3) determination of the physiological activities of the bacteria isolated from the sea; (4) interpretation of the rôle of these bacteria in the cycle of life in the sea itself

In the study of the occurrence, abundance and activities of bacteria in such a medium as the sea, in which they occur not in pure culture but as mixed populations, the methods employed are of considerable importance These methods are both direct and indirect In view of the small size of the bacterial cell, the relatively extreme dispersion of the bacteria and their comparatively low numbers in the ocean, any direct examination of the sea-water can tell very little concerning the occurrence and abundance of the bacteria; these cells should be concentrated, by removing much of the water, either by centrifugation, by filtration or by evaporation, before a microscopic examination is attempted Most of the methods commonly employed in the past for the study of the abundance of marine bacteria were cultural in nature; here belong the gelatin and agar plate methods, the dilution method and the enrichment culture methods. Since no single medium will allow the development of all the bacteria present, even in a small quantity of sea-water or sea-bottom material, various media have to be employed The early investigators limited themselves to counting bacteria by means of the plate method. At first the gelatin media were employed, soon followed by agar media, such as sea-water gelatin or sea-water fish extract gelatin and sea-water agar, with various modifications It was recognized, however, at an early date that the sea contains many bacteria which are unable to develop on the culture plate This led to the adoption of various dilution methods and specific enrichment culture methods. More recently there has been a tendency to use direct microscopic methods for the enumeration of bacteria both in the sea-water and in the sea bottom

The plate method presents certain advantages but also various distinct limitations The fact that one can determine the numbers of bacteria which are actually present in the sea in a living state, after they are allowed to develop on the plate, and the fact that one can isolate these bacteria from the plate for further study of their morphological and physiological characteristics are distinct advantages of the method However, not all the bacteria present in the sea are able to develop on the common plate, some of the most important organisms, such as the nitrifying, sulfur-oxidizing, nitrogen-fixing, not developing at all; but even those bacteria that are able to grow on the plate will not all

CROSS-SECTION OF *ULVA LACTUCA* . SHOWING FUNGUS INVASION OF TISSUE; STAINED WITH HAEMOTOXYLIN AND CONGO RED.

develop and form colonies. The plate method may thus give an unbalanced picture of the bacterial population of the sea. To meet these objections, Cholodny and others suggested the use of a direct microscopic method This method has certain advantages, since it gives a more correct picture of the abundance of bacteria in the sea, however, it does not enable one to distinguish the living from the dead bacteria or to separate the various types of organisms for further study of their physiological characteristics.

To determine the specific nature of the bacteria, the enrichment or elective culture method is usually employed, the sea-water or bottom material is added to a medium of specific chemical composition and the nature of the transformation brought about in the medium is determined. This method is very convenient for the purpose of demonstrating the occurrence of specific bacteria in the sea By combining the dilution method with that of elective culture, the relative abundance of the specific bacteria can be estimated. This method was used for the purpose of demonstrating and isolating some of the most important bacteria now known to be found in the sea The solution medium can be replaced by the silica-gel medium, which has found application in various investigations recently carried out at the Woods Hole Institution.[2]

No single method can be used for the study of the bacterial population of the sea as a whole Various methods have to be combined in order to obtain an insight into the nature and abundance of this population. For the study of the abundance of proteolytic bacteria, the gelatin plate may be used, for agar-liquefying bacteria—the agar plate, for cellulose-decomposing bacteria—the silica gel cellulose plate, for demonstrating the presence of various other specific bacteria—various special methods have to be adapted.

DECOMPOSITION OF *ULVA LACTUCA* BY BACTERIA IN SEA WATER MEDIUM; THE EXTREME RIGHT SHOWS THE THIN GRANULAR FILM OF BACTERIA ATTACKING THE EDGE OF THE ALGA

For study of the biochemical activities of marine bacteria, methods are employed which are based both on the nature of the organism and upon the specificity of the process under consideration These methods are in most instances adaptations of methods employed in general bacteriology. The most important phase of the subject, however, namely the study of the rôle of the bacteria in marine transformations under natural conditions, has scarcely been considered at all.

NATURE OF THE BACTERIAL POPULATION OF THE SEA

Fungi are either entirely absent in the sea or are found at infrequent intervals. Whenever reference is made to their occurrence in the sea, a closer examination of the data will reveal the fact that this was due either to contamination in

[2] S. A. Waksman, C. Carey, and H. W. Reuszer, *Biol. Bull.*, August, 1933.

MAGNIFIED SECTION
OF DECOMPOSITION OF *Ulva lactuca* BY BACTERIA, × 900, STAINED WITH HAEMOTOXYLIN AND CONGO RED.

the process of the preparation of the plates or to their chance infiltration from land and from dust (wind), especially at places close to shore The fact that the genera Aspergillus and Penicillium occupy a prominent place among the fungi which were thus commonly reported adds further weight to the above conclusion, since these genera comprise the common dust and windborne fungi. One need not exclude, however, the possibility that fungi play a part in the decomposition of algal material and Zostera, when exposed to the atmosphere, as shown in the figures Actinomyces are also either entirely absent or infrequently observed Yeasts have frequently been found, especially certain Torulae, but their rôle in marine processes has been studied but little

The bacterial population of the sea is quite characteristic It is distinct in nature from the population usually found on land, as shown by the more limited number of bacterial types found in the sea. Spore-forming bacteria, which comprise an important part of the bacterial population in soil, are practically absent in sea-water, although they may be present in considerable abundance in the sea bottom. Cocci are also of limited occurrence in the sea Motile rods and various types of vibrios, or comma-shaped organisms, usually make up the major part of the bacterial population thus far studied The poverty of bacterial species in the sea depends largely upon the specific nature of sea-water as a medium for the growth of these organisms

Certes observed in 1884 that only aerobic bacteria are present in the ocean; no anaerobic forms were noted. Bacteria were found to occur in the water to very considerable depths, namely, 5,100 meters Fischer determined that, on an average, 1 cc of sea-water contains 1,083 bacteria, with a maximum of 29,400 and a minimum of 0 More bacteria were found in the winter than in the summer months. The marine bacteria were shown to be morphologically and physiologically distinct from the land forms, most of them being curved or spirilloid in shape.

In 1892, Russell demonstrated that sea mud contains greater numbers of bacteria than the above lying water: at a depth of 50 meters, there were only 121 bacteria in 1 cc of water, while 1 cc of mud contained 245,000 bacteria. Russell believed that the bacteria settle upon the mud in the form of spores or vegetative cells from the upper layers of water. The nature of the mud and its depth were found to influence the number of bacteria considerably. Most of these bacteria were proteolytic and were able to reduce nitrate to nitrite. According to Bertel, away from the coast in the open sea, the bacteria increase in numbers with depth. A marked difference in the numbers of bacteria in sea-water and in sea mud was also reported by Smith, Bavendamm and others. As many as 16,000,000 bacterial cells were

found in 1 gram of mud from the mangrove swamps of the Bahamas. Many of these bacteria were strongly agar-liquefying, pointing to their capacity of decomposing the organic complexes which are synthesized so abundantly by the algae in the sea

In a recent study carried out at the Woods Hole Institution,[3] it was found that in ocean waters close to land and at sufficient depth to preclude agitation of the bottom by currents and wave motions, the numbers of bacteria are very small, usually not more than a few cells per 1 cc of water. The depth of the water and the nature of the sea bottom are of importance in this connection Along shores receiving considerable land drainage, the numbers are much greater The bottom deposits, especially the mud bottoms, are much richer in bacteria than the waters A marked parallelism was found between the plankton organisms and the abundance of bacteria in the water, as well as a definite relation between the organic matter or humus content of the mud and the abundance of bacteria

Among the specific bacteria commonly found in the sea, the nitrifying and denitrifying organisms have attracted particular attention. The formation of nitrates in the sea and their disappearance have aroused considerable interest. It was at first believed that the nitrates are brought into the sea from land or by atmospheric agencies. However, more recent evidence seems to point to the fact that nitrate formation is largely a result of bacterial activities in the sea itself. Thomsen and later Issatchenko, Lipman and others established the fact that, although nitrifying bacteria are not found in the surface waters of the sea, they can be readily demonstrated in the sea bottom. The investigations carried out at the Woods Hole Institution seem to point in the same direction.

As to the bacteria capable of reducing nitrate in the sea, one must avoid confusing nitrate-reducing bacteria with denitrifying bacteria: the first may reduce the nitrate only to nitrite and possibly to ammonia, while the latter break down the nitrate to atmospheric nitrogen or to gaseous forms of nitrogen Although nitrate-reducing bacteria are present abundantly in the sea, denitrifying bacteria are found there but seldom, except possibly near shore or in the sea bottom. The results of Issatchenko, Butkewitch and those obtained recently at Woods Hole point in that direction. The mere fact that nitrite can be formed from nitrate by bacteria in the sea is no proof as yet that it leads to losses of nitrogen, since the nitrite can be assimilated by the phytoplankton organisms in their nutrition.

The presence in the sea of bacteria capable of bringing about the fixation of nitrogen has also attracted considerable attention. Benecke and Keutner were the first to isolate from the sea the aerobic *Azotobacter* and the anaerobic *Clostridium pastorianum,* the first organism occurring largely in the plankton and the second in the lower layers of water Keutner, Keding and Issatchenko later demonstrated that Azotobacter cells are found on various algae growing in the sea; the same was frequently true of Clostridium and of accompanying bacterial forms Reinke believed that a certain form of symbiosis exists between the algae and the Azotobacter, similar to that of the nodule bacteria and the leguminous plants A typical culture of the aerobic, nitrogen-fixing bacterium, *Azotobacter chroococcum,* isolated from the sea-water, in the neighborhood of Woods Hole, is shown in the accompanying figure Unfortunately, the importance of these organisms in ocean life has not yet been definitely established. Their occurrence in sea-water and in the sea bottom under different conditions, at

[3] H. W. Reuszer, *Biol Bull.*, 1933. (In press.)

AZOTOBACTER CHROOCOCCUM

THE AEROBIC NITROGEN-FIXING ORGANISM, ISOLATED FROM THE SEA, × 1650

different depths and at different temperatures, as well as the conditions influencing their activities, still remain to be determined.

Among the bacteria capable of bringing about the decomposition of marine residues, the agar-liquefying organisms, which are particularly abundant in the phytoplankton, have attracted considerable attention These bacteria are capable of producing an enzyme which liberates soluble sugars from the complex carbohydrates which form the important constituents of the marine plants The occurrence in the sea of cellulose-decomposing, of fat-splitting, of proteolytic and of various other bacteria has also been established.

Decomposition of Plant and Animal Residues and Transformation of Nitrogen

In order to understand the mechanism of the decomposition of the organic residues, it is important to know their chemical nature. Among the members of the phytoplankton in the sea, the diatoms are most abundant in the colder regions, while the Peridineae and the Schizophyceae are present largely in the warmer regions. The chemical composition of several members of the phyto- and zooplankton has been reported by Brandt as follows:

Chemical constituents, per cent of dry material	Nature of organism		
	Chaetoceras	Ceratium	Copepods
Protein	10 0	13.0	59.0
Chitin			4 8
Fat	2 8	1.3	7.3
Soluble carbohydrate	22 0	39.0	22 5
Cellulose	0	41 5	0
SiO_2	54 5		
Salt and other ash materials	10 7	5 2	9 2

In general, the organic carbon of the plankton is found to range from 14 to 48 per cent, the nitrogen from 1 5 to 10 6 per cent, and the ash from 13 to 65 per cent The diatoms are richest in ash and lowest in nitrogen, while the zooplankton is low in ash and high in protein Only the Peridineae contain cellulose, while the hemicelluloses form the most abundant group of carbohydrates among the diatoms and the various lower and higher algae. Fats are present abundantly, while the nature of the proteins still remains to be studied. It is of interest to note that 1 gram of dry matter in the plankton corresponds to 500,000 copepods, to 65,000,000 peridinia and to 675,000,000 diatoms.

It is of interest to compare the above analyses with that of a typical marine alga, namely, *Fucus vesiculosus* (see table on p. 47).

When the dead plants and the animals, their excreta, the various residues and degradation products undergo decomposition in the sea by the action of the bacteria, a number of organic and mineralized complexes are formed. A part of the organic substances may become soluble in the sea-water, while

Chemical constituents	Per cent
Protein	5.4
Fat	2.3
Alcohol-soluble material	6.7
Cold water-soluble organic matter	13.6
Hot water-soluble organic matter	7.8
Pentosan*	28.7
Uronic acid anhydride*	27.5
Cellulose	3.9
Ash	13.9

* These two fractions represent largely the same chemical complex determined by two different procedures.

some of the residual substances as well as the synthesized bacterial cells may drop to the bottom and contribute to the formation of the marine humus.

The most important compounds formed in the process of decomposition of the marine plant and animal residues are ammonia, carbon dioxide and phosphates; the ammonia is oxidized by certain specific bacteria to nitrite, and then to nitrate. These compounds are thus made available for the nutrition of the marine plant population, namely, the phytoplankton and the algae. Raben and a number of other investigators demonstrated the fact that the deep water in the open ocean contains more nitrate and phosphate than the upper layers in which phytoplankton organisms are active; the North Sea waters contain more nitrate and phosphate in the summer than in the winter months. According to Brandt, the nitrate of the sea is continually renewed by rain and by rivers; he suggested that the denitrifying bacteria reduce the concentration of nitrates in warm regions, which thus accounts for the reduced phytoplankton production. Harvey concluded, however, that the introduction of nutrients from land into sea plays only a minor part, when compared with the quantity of nutrients formed yearly from the dead organic residues in the ocean itself. After death, the algae and the animal members of the plankton sink to the bottom and are decomposed there by bacteria, with the result that the phosphate and nitrogen are liberated in an available form. These mineralized nutrients are then brought to the upper layers by vertical circulation. The bacteria are thus recognized as playing a most essential function in the cycle of elements in the sea.

Organic Matter in Sea-Water and in the Marine Bottom

The question of the abundance, chemical nature and function of the organic matter found in the sea in an unorganized form, either in solution in the water or in a solid state on and in the

ZOSTERA
HEALTHY LEAF, SURFACE VIEW, × 600.

sea bottom, presents a number of highly important problems in which the activities of the bacteria play a prominent part. The function of the dissolved organic matter in the nutrition of the marine animals has been emphasized by Pütter. This theory was submitted to considerable criticism by Krogh and others. Pütter's figures for the dissolved organic matter in the sea were shown to be too high, and some of this organic matter was shown to be due to

ZOSTERA LEAF
AFTER 30 DAYS OF DECOMPOSITION, × 400.

the suspended bacteria, protozoa and unicellular plants present in the water Although a part of the organic matter in solution may be liberated by the algae, there is no doubt that another part is produced by the bacteria in the process of decomposition of the plant and animal residues in the ocean.

Another source of organic matter in the sea is the marine bottom. This organic matter can be designated as "marine humus," because of its similarity in chemical nature, and probably in origin, to the humus found in soils The concentration of this humus in the marine bottom varies considerably, namely, from 0 5 per cent. in the case of sand bottoms to nearly 10 per cent. in the case of certain mud bottoms In some localities, such as protected harbors or fjords, the mud bottom may contain as much as 20 per cent humus. This humus is best calculated from the organic carbon content, by the use of a certain factor Boysen-Jensen suggested the use of a factor of 2, assuming that the carbon content of the humus is 50 per cent However, a study of the chemical composition of the humus brought out the fact that this factor should be lower than 2, namely, 1.923, due to the presence in the humus of lignin-like complexes with a high carbon content.

One of the most important characteristics of this marine humus is its carbon-nitrogen ratio Boysen-Jensen found this ratio to vary from 8·1 to 12:1, with an average of about 10:1 These results were fully confirmed by other investigators When one recalls the fact that a similar ratio of carbon to nitrogen holds also for soils, the similarity of the marine humus to soil humus becomes even more apparent Organic complexes similar to those found in soil humus can also be isolated from the marine humus There are several reasons for the similarity. (1) a part of the marine humus is of terrestrial origin, being brought into the sea by streams and rivers; (2) the marine humus, just as the soil

ZOSTERA LEAF
AFTER ADVANCED DECOMPOSITION, × 400.

humus, is formed by similar microorganisms in a very similar manner Certain differences observed in the chemical nature of the humus can easily be accounted for by the fact that marine residues, from which all or part of the humus is formed, are different in chemical composition from the land residues from which all the soil humus is formed

The organic matter in solution in the sea-water as well as the humus in the mud are only slowly acted upon by bacteria, otherwise neither form of organic matter could be present in great abundance in the sea. However, even their slow decomposition is sufficient to provide a certain amount of available energy and nutrients for various bacteria living in the water and especially in the sea bottom.

Truly, the life of the plant and animal world in the ocean is variously dependent upon the manifold activities of the oceanic microscopic population composed principally of bacteria

The author is indebted to Mr C E Renn for the preparation of the sections of the marine plant material and to Dr. H. W Reuszer and to Mr C E Renn for the preparation of the photographs used to illustrate this paper.

CONDENSED BIBLIOGRAPHY

W Bavendamm, *Arch. Mikrob*, 3 205–276, 1932. W. Benecke and J. Keutner, *Ber. deut bot Gesell.*, 21: 333, 1903. R Bertel, *Bull Inst Oceanogr. Monaco*, No. 224, 1912 P. Boysen-Jensen, *Rept. Danish Biol Sta*, 22: 5–39, 1914 K Brandt, *Wiss. Meeresunters Kiel*, N. F 4 213–230, 1899; 6: 23–79, 1902, 18· 185–429, 1916–1920, 19: 251–252, 1919. W. C. Butkewitch, *Trans. Russian Oceanogr. Inst.*, 2· No 2, 1932 A. Certes, *Compt. Rend. Acad. Sci.*, 98. 690–695, 1884. N. Cholodny, *Centrbl. Bakt Abt.*, II 77. 179–193, 1929. G H. Drew, Papers from Tortugas Laboratory, Carnegie Inst Washington, 5· 15–191; *Jour Mar Biol. Ass.*, 9· 479–524, 1913. B. Fischer, *Centrbl. Bakt*, 15. 657–666, 1894; Ergebnisse der Plankton-Expedition der Humboldtstiftung, Lipsius & Tischer., Kiel and Leipzig, 4: 1894. H W. Harvey, "Biological Chemistry and Physics of Sea Water," Cambridge Univ. Press, 1928 B L Issatchenko, "Récherches sur les microbes de l'ocean Glacial Arctique, Petrograd, 1914. M. Kednig, *Wiss Meeresunters. Kiel*, N. F. 9: 273–309, 1906. K. Kellerman and N R Smith, *Jour. Wash. Acad. Sci*, 4: 400–402, 1914. J Keutner, *Wiss. Meeresunters Kiel*, N F 8· 27–55, 1905 A Krogh, *Rapp Proces-Verbaux Cons. Intern Expl Mer*, 75 1–36, 1931 C B Lipman, Carnegie Inst. Washington, Dpt Marine Biol., 19 179–191, 1924 H. Molisch, *Centrbl. Bakt.*, II. 65· 130–139, 1925 G Nadson, "Microorganisms as Geological Agents" (Russian), St. Petersburg, 1903 A Putter, *Pfluger's Arch. Physiol.*, 204 94–126, 1924 E. Raben, *Wiss. Meeresunters. Kiel*, 11: 119–132, 1910. J Reinke, *Ber deut bot. Gesell.*, 21 481, 1903 H. W. Reuszer, *Biol. Bull*, to be published, 1933 H. L. Russell, *Bot Gaz*, 17: 312–321, 1892 N R Smith, Carnegie Inst Wash, No 344· 67–72, 1926 A. Thienemann, *Die Naturwiss*, 13· 589–600, 1925. P. Thomsen, *Ber deut bot. Gesell*, 25 16–22, 1907, *Wiss Meeresunters Kiel*, N. F 11· 1–27, 1910. S. A. Waksman, *Soil Science*, August, 1933.

MEAT RESEARCH IN THE UNITED STATES

By E. W. SHEETS

CHIEF, ANIMAL HUSBANDRY DIVISION, BUREAU OF ANIMAL INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

AN avowed purpose of meat research is to adapt the products of the stock grower to the changing needs of the consumer. Of equal importance is the problem of producing those preferred meats economically under the varied conditions prevailing in feed lot, range and forest These aims are no different from those that obtain in other industries Manufacturers all endeavor to develop a better product and to produce it more economically Edison's carbon filament, incandescent lamp, revolutionary at the time, has long since given way to tungsten Automobiles, tires, gasoline, roads and even traffic police must change to meet the changing needs of a changing world Meat has changed too, particularly in size or weight of cut, but the hunt for a tender steak or a juicy roast is still a hunt in the minds of many consumers, too much a hunt for the satisfaction of either those who eat or those who produce the meat Meat research is the effort of the live stock and meat industry to standardize its goods

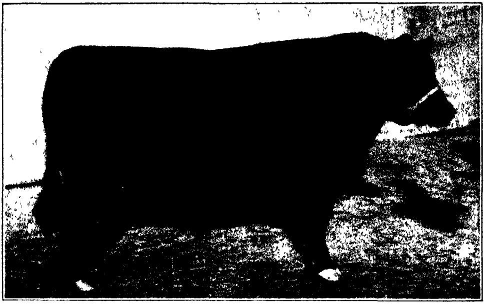
A third responsibility of meat research is to aid in the adaptation of live stock to current needs—a continuing adjustment that will give permanence, elasticity and soundness to the farming program of the nation Live stock on grass offer to-day a solution to the problem of crop surpluses Each acre of cultivated crop land converted to meadow crops and pasture will yield approximately half the live-stock feed it did before. Since 70 per cent. of the total quantity of harvested crops grown in the United States is fed to live stock, general conversion of crop land into pasture or meadow will result in less total live-stock production The use of maximum quantities of pasturage and hay crops and a minimum of grains in live-stock production must not be done at the expense of quality, however. It is here that meat research is called upon to play an important rôle.

Meat research goes back to the first hunter who discovered that muscle from the back of his kill was more tender than pieces from the shoulder The inventors of the first broiler (the forked stick), the maker of the first stew in a clay vessel, of the first cured ham, bring down the line of meat investigators to the tenderness comparisons of Lehmann in Germany before 1900, to the cooking studies of Grindley, Majonnier and others in Illinois in 1907, to the analyses of the food value of meat for the U S Department of Agriculture, by Atwater and Woods in 1894 and 1896, and Langworthy and others after 1900

Contemporary meat research includes, among many projects, the efforts of Schmidt and his colleagues in Germany to develop strains of hogs with a greater proportion of lean to fat, and of the Danish cooperative organizations to improve, through both breeding and curing, the quality of Wiltshires which that country exports to England.

To Dr. Moran and associates in the Low Temperature Laboratories in Cambridge, England, we owe much for their study of the effect of freezing and storage upon meat shipped long distances. They have added to our meager knowledge of what meat really is.

Meat is a complex and, as yet, rather puzzling product. We have seen its general structure, noted its physical proper-



DESIRABLE BEEF TYPE

Grand Champion Steer at One of the International Live-Stock Expositions

ties and studied the composition of a number of substances found in it. Yet until recent years we have not been able to make definite comparisons of muscle to learn the effects of breeding, feeding and management upon palatability and food value. One recalls the definition of electricity given by the old high school physics teacher "Electricity is a strained condition of the atmosphere in and around the thing electrified." Our definition of meat was almost as vague when this meat research was begun.

Eight years ago the National Live Stock and Meat Board, which represents all branches of the live-stock industry, called a meeting to consider the establishment of a cooperative meat research program. Representatives were present from the state agricultural experiment stations, the Institute of American Meat Packers and the U. S. Department of Agriculture. Organization was effected, a program adopted and each institution undertook those studies in which it was most interested and best equipped. Once a year the cooperators meet to present results, discuss methods and suggest advances for the coming year.

The plan of study was divided into three parts: Factors of production, of processing (storing, freezing, curing, etc.) and of cooking. Palatability, food value and economy are the three measures used.

Cattle, hogs and sheep of various breeds, ages and sex are fed and handled under similar conditions. Various rations and methods of management are also compared. At the conclusion of the feeding or growing period the animals are slaughtered, chilled, cut, sampled and tested under comparable conditions.

Freshly slaughtered animals are chilled to 34° to 36° F. and held at this temperature for a standard length of time. Samples are then roasted by standard methods suited to the kind and cut. For example, every rib roast of beef is cooked to the rare stage, that is, until the meat at the center registers 62° C. as shown by a special meat thermometer. Hot

slices from these roasts are eaten and graded by a committee of five for aroma, texture, flavor, tenderness and juiciness. A cooked sample is also tested mechanically for tenderness in a power shear. Mechanical tests for juiciness are being developed.

At the beginning of the experimental feeding period a grade or description of the conformation, character and fatness of the individual animals is recorded. The same is done at the close of the feeding period and after the carcass is dressed. These characteristics are then compared with the yield and palatability of the meat to determine the visible evidences of quality.

Physical and chemical analyses of carcasses, or of representative samples, give an accurate check on composition, particularly of fatness, as it relates to grade, yield, cooking losses, cooking time and palatability.

Quantitative determination of the content of the various proteins, connective tissues, enzymes and flavors have not yet developed to the stage where they can be applied. Neither has technique for a comparative histological examination been perfected. The relationship between composition and structure may provide a means for determining tenderness, flavor and juiciness more accurately than the methods now used.

Another difficulty has been the individual variation in the inherent character of the experimental animals. There is more difference between individual animals in the same lot than between the averages of the two lots. We are forced to use larger numbers in each lot; to depend upon the law of averages to offset the error of individual variation until more uniform experimental animals can be produced.

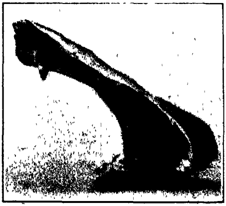
The hope of obtaining more uniform

A BRAHMAN CROSS

BRAHMAN BLOOD FROM INDIA HAS BEEN TRIED TO IMPROVE THE RUSTLING CAPACITY OF STEERS IN DRY, HOT, TICK-INFESTED AREAS.

THE LONGHORN OF TEXAS FAME
AMONG THE LAST OF HIS RACE

experimental animals had its genesis in our first disappointment over the variation among steers of the same breed and age—steers that looked alike but performed differently That disappointment made us think of other animal material which possibly might be better adapted to the working out of some of the complicated details which confronted us. Our minds went back to guinea-pigs upon which Dr. Sewall Wright, now of the University of Chicago, began extensive inbreeding investigations in the Bureau of Animal Industry more than 20 years ago He started with 35 matings and continued by brother-sister matings These families have been closely bred so long that, though only 4 of the 35 original matings remain, practically all variations in color, fertility, longevity and weight for age which are due to heredity have been eliminated



LOW QUALITY BEEF RIB
CONTRAST SIZE AND SHAPE OF MUSCLES AND AMOUNT OF FAT WITH THE HIGH QUALITY BEEF RIB.

HIGH QUALITY BEEF RIB
THE FULL MUSCLING AND THICKNESS OF FAT LAYERS SHOW THE EFFECT OF BEEF BREEDING AND LIBERAL FEEDING.

CORRIEDALE RAMS
THESE EXCELLENT MUTTON SHEEP ARE BEING TRIED TO INCREASE THE WOOL CLIP OF LAMBS FROM NATIVE EWES

From this work we now know that such characteristics as fertility, rate of gain and rate of maturity are influenced by inheritance The principle has been applied in a similar system of breeding with hogs which have reached 6 generations of brother-sister mating One strain of Chester Whites has not only maintained the quality and growthiness shown by the foundation stock but has actually shown improvement in these respects

Studies on different breeds and strains within the breed utilize an increasing number of animals and amounts of feed. No state station is in position to maintain and feed the progenitors of several strains of cattle or sheep or hogs until progeny can be matured and tested The Department of Agriculture, however, possesses, through transfer from the War Department, 56,000 acres of Montana range that was formerly Fort Keogh of frontier days. Adjacent to the department's 28,000-acre sheep station at Dubois, Idaho, are extensive mountain pastures made available to the experimental flocks through the Interior De-

COMMON TO CHOICE LAMB RIBS
NOTE DIFFERENCE IN SIZE AND SHAPE OF MUSCLE AND THICKNESS OF FAT.

A 2-TON LITTER

FOUR THOUSAND AND FIFTY (4,050) POUNDS OF HOGS FROM A SINGLE LITTER AT 6 MONTHS

partment Less expensive arrangements to maintain cattle and sheep would be difficult to make and the 30-odd members of our cooperative research program can look forward to the day when the problem of individual variation in experimental animals will be greatly lessened

A product of this breeding work has been the discovery that strains or blood lines vary as to efficiency in the use of feed and desirability of the meat produced. Progeny of the different strains are fed and tested in what are called "record-of-performance" trials. For example, calves from selected matings of both beef and dual-purpose cattle are individually fed until they reach 900 pounds live weight. They are then slaughtered and their meat tested according to the regular procedure. The dressing percentage of 14 beef type calves ranged from 57.6 per cent. to 61.9 per cent. and the tenderness of their rib roasts from "moderately tender" through "tender" to "very tender."

Similar variation was also shown in the average performance of representative pigs from different litters Handled under the same conditions the average daily gain of the 4 pigs selected to represent each of 12 litters ranged from 0.46 to 1 41 pounds and the feed consumed per hundred pounds gain from 360.7 pounds to 503 6 pounds The yield of low-priced fat back varied as much as 2 9 per cent. and of the more-demanded ham 2 3 per cent The superior lines are being preserved and crossed on the theory that mating the high values will produce, sometime, still higher values. We aim for uniformity in experimental stock. We hope, in addition, to produce pure strains of cattle, hogs and sheep that will make cheaper gains and yield still more tender, juicy steaks and chops.

Some of the facts already obtained from these meat studies are contrary to ideas and beliefs commonly accepted in the trade. One of the most striking deals with the color of the lean tissue of beef. Beef lean after being cut about one half hour is normally a bright, cherry red. Occasionally some steer or heifer carcass will show muscling of a

dark or almost blackish red The cause for these "dark cutters" is as yet undetermined, but dark meat has always been classed and sold as tough and inferior regardless of its degree of youth, finish or conformation

Our investigations have shown that dark beef is just as palatable and tender as bright beef of similar quality in other respects In fact, after they are cooked, dark and bright beef can not be distinguished either in appearance or eating quality

It is true that the beef from old cattle tends to be darker and may be lacking in tenderness, but to paraphrase and abbreviate the adage about the crow "all beef that is dark is not tough" We hope to discover and eliminate the cause of dark-cutting beef because it is unattractive and less appealing to consumers That seems, however, to be its greatest fault

Another point in which our results do not conform to accepted standards is in regard to fatness The meat trade has always assumed that the more fat a carcass carried the better the meat That is largely true Amount of fat is a good guide to purchasers who are not familiar with all the indications of quality Fat meat is usually "well-finished" meat There are some exceptions to the rule, however We will be able to give consumers more value for their money as we learn more about the effects of fattening on tenderness, flavor and juiciness. Our results with three-year-old steers fed grass alone, compared with those fed grass and a supplement of grain, is a good illustration The steers fed grain were heavier, fatter, more attractive, and dressed a higher percentage of carcass than those given only pasture The rib cuts from the grain-fed steers analyzed 38.5 per cent of fat, those from the other lot only 30 per cent. The standard rib samples used for cooking averaged 12.5 pounds in weight from the fatter steers and only 10 pounds from the thinner cattle Here is where the consumer becomes interested! The 10-pound ribs contained just as many pounds of lean and protein as those weighing 2½ pounds more and no more bone. In other words, the food value of the ribs, excepting for the fat, was just as great in ribs that would have weighed less and cost less to buy The palatability of the two sets of ribs was very similar. The additional fat did increase slightly the richness of the juice, but the difference was too small to offset the extra cost of those heavier ribs

Thinly fleshed cattle and lambs have given the poorest flavored meat that we have handled through the laboratory In contrast, among the best, if not the best, beef was from six show steers, all

A PINEY WOODS ROOTER

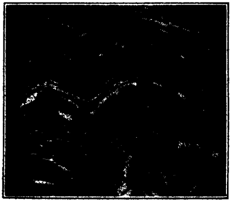
of which carried a so-called "wasty" finish. Our facts are too few to warrant a definite statement as to the degree of fatness that will give the product the greatest consumer value. Results to-day indicate, however, that, although increasing fatness is desirable, it can, under some conditions, cease to be a virtue and become another "surplus."

A brief summary of some of the other results already obtained illustrates the breadth and purpose behind the research program that is being conducted by these cooperating state and national organizations.

Neither breed nor character of ration, as far as the studies have been carried, has been found to cause significant differences in the palatability of meat.

The chief disadvantage of well-fed lambs and calves produced by "scrub" instead of "improved" breeding appears to be in the weight, dressing per cent., attractiveness and storage adaptability of the carcass rather than in the palatability of the meat.

Heifers fatten more quickly than steers, but the meat from the two sexes is similar in palatability when other conditions are equal.



PHOTOMICROGRAPH OF BEEF MUSCLE

SHOWING BUNDLES OF MUSCLE FIBERS, CONNECTIVE TISSUE AND FAT. IT IS WITH VARIATIONS IN THE ARRANGEMENT AND CHARACTER OF THESE CONSTITUENTS THAT SOME MAJOR PROBLEMS IN QUALITY OF MEAT ARE CONCERNED.

ROASTED EXPERIMENTAL LAMB LEG

STANDARD SLICES ARE CARVED FOR TESTING BY THE GRADING COMMITTEE.

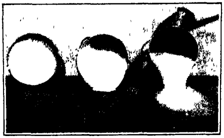
Corriedale rams have improved the quality of wool production in Hampshire type native ewes without decreasing the mutton quality.

Suckling lambs on good pasture made just as large gains and produced just as desirable meat as similar lambs fed grain in addition to grass and mother's milk.

Wheat produced as large gains and as firm and palatable pork as corn.

Soft and oily pork produced by feeding peanuts to the hogs was practically as desirable in flavor and aroma of the roasted fresh meat as firm pork produced by corn-fed hogs.

Processing problems deal with methods for handling meat after the animal has been dressed. The task is to take the animals that the stockmen have produced and present the meat to the consumer in its most palatable, economical and merchantable form. Methods of chilling, cutting, curing and ripening are of first importance—chilling to keep the meat wholesome and attractive; cutting to divide the muscles so that each patron can secure just the weight and quality



HARD, SOFT AND OILY LARD
DIFFERENCES IN FIRMNESS WERE DUE TO RATIONS FED.

needed for broiling, roasting or stewing, curing and ripening to develop the maximum flavor and tenderness inherent in the meat.

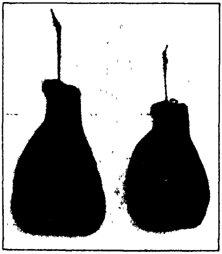
Adaptations of refrigeration units have been devised to meet the needs of farm communities and of individual farms and plantations A decrease in the spoilage of farm-cured meat and an increase in its palatability have resulted

Cutting meat so that the muscles will be divided in a manner that provides cuts suitable for small families is a move in the direction of more complete utilization of meat The National Live Stock and Meat Board has pioneered in this work among commercial meat retailers.

A search for milder, more desirable cures for farm-cured meat, and rapid cures for commercial meat, the retention of mellow succulence in aged hams and a study of the adaptability of cured lamb and mutton to the farm and to commercial markets have been the chief activities along the curing line. A more detailed study of bacterial action in relation to temperature and the palatability of cured meat is now being made.

Ripening fresh meat consists in hanging it in cold storage for such length of time as will permit the enzymes and other autolytic agents to hydrolize the tissues and develop flavor. We have found that lamb legs make much more tender roasts after a storage of 7 to 10 days than if eaten within the first week after the lambs were slaughtered Longer ripening than 10 days did not improve them materially Well-finished beef is often ripened for six weeks, but our studies have not been complete enough, as yet, to determine the respective merits of short and long aging for beef These ripening experiments offer a fertile field for possible improvements in the palatability of meat The chemist, physicist, histologist and bacteriologist will probably be able to show us how to increase materially the desirability of meat from animals that have not had the advantage of optimum feed conditions.

Coupled with the palatability and food value of meat is economy of preparation and serving. Home economics workers are studying the problems of cooking time, cooking losses, fuel consumption and number of attractive servings in relation to the kind and cut These workers have shown that by controlling oven temperature and keeping it moderate most of the time they can actually cut down the cooking losses by a pound or so on a 10-pound roast Fat



"SHANKY" AND WELL-MUSCLED HAMS
DIFFERENCES IN LENGTH AND THICKNESS ARE DUE TO BREEDING.

meat roasts more rapidly (minutes to the pound) than lean. Boning and stuffing such cuts as shoulder of lamb or pork converts them into delicious roasts easy to carve and economical to serve A more complete detailed study of the effect of heat on meat will follow the development of better technique in chemical and histological comparisons.

Much has been learned by various investigators about the part meat plays in promoting growth and health, and preventing disease; the value of its complete proteins, its minerals and vitamins, the effect of its palatability upon digestive processes, the value of lean meat in preventing pellagra, the value of liver in preventing anemia We hope to fractionate still further these complex substances so that meat and products of meat can be of greater service to all.

The cooperation between the many state and national laboratories in meat research is a "result" that I mention last in order to give it emphasis. I know of no finer example of concerted effort than this work gives We have had to pioneer, to reach beyond the known in both subject-matter and method New discoveries, new ideas or even "hunches" have been made common property to the advantage of all. We serve a great branch of agriculture We have much to do We can do it better and more quickly through cooperation.

DEFOLIATION ACTIVITIES OF GRAY SQUIRRELS IN AMERICAN ELM TREES

By Dr. CARL G. DEUBER
ASSISTANT PROFESSOR OF PLANT PHYSIOLOGY, YALE UNIVERSITY

Each spring a shade-tree drama of considerable interest is enacted within a hundred feet of my office windows on a university campus, and it is one that may be observed throughout all New England and wherever the gray squirrel finds life feasible in the vicinity of American elm trees on well-kept lawns. The situation has to do with the gray squirrel making his entire diet practically of elm seeds during the latter part of May and in early June. These seeds are of little consequence to the tree or to man in that they are produced in abundance and the reproduction of elm trees by seedlings is a relatively simple matter. But this situation becomes a shade-tree and a lawn problem when the squirrel's habit of eating this delicacy is examined—and not necessarily closely.

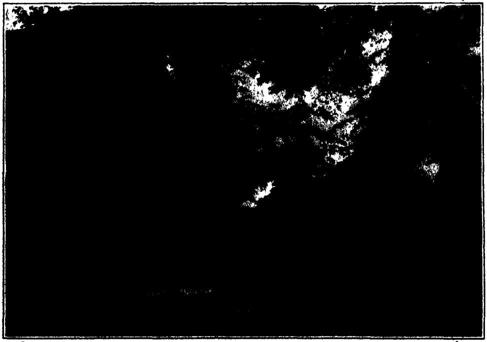
As the elm seeds ripen in the latter part of May the gray squirrel scampers out to within six inches of the ends of even the smallest branches, eats a few seeds out of the seed cluster on that particular branch, then quickly reaches out to the seed cluster of neighboring branches. These are usually inconvenient to eat from that position, so he draws the twig to his mouth with a fore paw and nervously bites it off in the midst of the seed cluster. After stripping off most of the seeds or merely slitting open the papery covering over the kernels of attached seeds and deftly

LAWN AT FARNUM GARDEN, YALE UNIVERSITY,
LITTERED WITH ELM TWIGS CUT BY TWO PAIRS OF SQUIRRELS. MAY 27, 1933.

extracting the rich, oily kernels, he allows the twig to float to the ground. Since these twigs have fresh new leaves a tree health problem is presented in which it becomes desirable to evaluate the effect of this defoliation on the well-being of the shade-tree. And since the leafy twigs must necessarily land on the lawn a problem in maintaining the lawn free of this leaf litter is presented to the yardman. This does not mean that the matter is one of tragedy, necessarily, but one certainly worthy of examination.

Before analyzing the tree problem it must be emphasized that the gray squirrel is a package of energy and industry. These traits bring him under surveillance as a pest in more than one respect. Several squirrels were timed on their twig-cutting activities. One individual was chewing off three twigs per minute, another pair kept five and seven twigs floating down in the air in the course of two respective minutes. The gray squirrel loses time only when a new feeding position is taken. Toward the end of the seed crop the squirrels will work even the outermost branches, fifty feet or more from the ground, giving the appearance of furry plummets.

Since this feast of the squirrels on elm seed comes at the season when a professor's time is a trifle more his own than during the winter period, due to the ancient invention of final examinations, it was decided that this year the squirrels would be held to an accounting for their spree on my favorite tree. Morning and evening for five days during the midst of the twig-cutting lark the task of collecting and tabulating the damage was self-assigned. On the first day the twig crop reaching the lawn amounted to 517 items. This was calculated to represent 2,585 leaves having a surface area of 75 square feet. This leaf area, a little larger in size than an 8 by 9 rug, was laid low by two squirrels in one tree. The next two days were cloudy and rainy and the leaf carpets were



YOUNG SQUIRRELS FEEDING UNDER A "FAVORITE" AMERICAN ELM TREE ON A YALE UNIVERSITY CAMPUS. JUNE 8, 1932.

LITTER OF THREE YOUNG SQUIRRELS OCCUPYING A BIRD HOUSE IN A ROSE ARBOR AS A NEST. MAY 26, 1933.

approximately 7 by 9, but on the fourth, a hot, sunny day, these squirrels were hungry and industrious, for they eliminated 892 twigs with a leaf area of 131 square feet—a 10 by 12 rug with a margin Incidentally, 312 linear feet of twigs had held these leaves in the sun Although data were taken for only five days, the seed-eating and twig-clipping covered a period of ten days—it ceased when the seeds gave out. It is conservatively estimated that more than 500 square feet of leaf surface were chewed off this one elm tree by two squirrels.

Up the hill at the botanical garden a beautiful, large, isolated American elm was found supporting two pairs of gray squirrels The tree had been sprayed with arsenate of lead during the week, but this did not deter the squirrels. At nine o'clock one morning the lawn at the foot of this tree was literally covered with elm twigs cut the previous day and on this morning. A count revealed 2,886 twigs, 14,430 leaves with a leaf area of 421 square feet A rug 20 by 20 would fit quite a large living room. This tree probably had 1,000 square feet of leaves eliminated this spring by the two pairs of squirrels.

The meaning of this defoliation of elm trees in terms of the health and vigor of the tree bring forth speculations which demand reflection rather than hasty judgment. Trees suffer from and are benefited by defoliation, depending on a variety of factors. Trees are sprayed annually to prevent the devastating effects of insects, such as the elm leaf beetle. The orchardist must follow a more or less rigid pruning program in order to encourage and maintain fruitfulness, and the nurseryman trains and shapes his tree stock with specific objectives in mind.

Defoliation, irrespective of its extent, eliminates food-manufacturing organs from a tree. By using a conservative figure for the rate at which dry matter is synthesized by green leaves active six hours a day and during ninety days, some basic data for further discussion can be obtained. Five hundred square feet of leaves would have the capacity

to synthesize over 1,200 pounds of dry plant material If an elm tree has a million leaves the elimination of 500 square feet of leaf surface would decrease that tree's potential capacity by approximately 2 per cent But if there were but one half this number of leaves and the defoliation was to the same extent, then the reduction in food and tissue manufacturing would be 4 per cent This latter value is suggested as the probable reduction in the synthetic powers of the first elm tree described earlier in this article. The true significance of the damage done this tree by one pair of squirrels in the spring over this or many years by the elimination of healthy foliage is practically impossible to state. But there are other considerations.

The American elm is naturally found growing in rich alluvial soil and prefers moist bottomlands. It is further characterized by an extensive and shallow root system. The natural environment of the American elm is not frequently encountered on a lawn or along a city street, so that the planted tree often shows the effect of a lack of sufficient water during midsummer. Although the roots may be firmly established and

ELM TWIGS IN BASKET, 198 IN NUMBER, REPRESENTING ONE MORNING'S TWIG-CUTTING ACTIVITY OF ONE PAIR OF SQUIRRELS. ALSO TYPICAL ELM TWIGS CUT IN THE MIDST OF THE SEED CLUSTERS. MAY 23, 1933.

ELM SEEDS
THE FOOD THE SQUIRREL SEEKS IN ELM TREES DURING THE LATE SPRING MAY 23, 1933.

of great extent, the foliage is so constructed that water, as vapor, is lost at a more rapid rate from the leaves than the roots can secure it from a relatively dry soil One remedy is to adjust the extent of the foliage surface to the capacity of the roots to supply water. The defoliation by the gray squirrel may therefore be a real benefit in helping to establish a more suitable ratio between the leaf area losing water and the capacity of the roots to supply water.

The brief feeding period of the gray squirrel upon elm seeds, which involves an appreciable defoliation, can be looked upon as about as beneficial as destructive so far as the well-being of the tree is concerned. Observation indicates that the gray squirrel seeks the most vigorous American elm trees in his vicinity—obviously for the abundant seed crop they bear. The worst score against the gray squirrel is the nuisance he creates by daily littering otherwise well-kept lawns with leafy twigs. The expressions of several yardmen on this point are not complimentary to the squirrel. But so long as natural laws prevent the gray squirrel from becoming too numerous, we can perhaps share our elm trees with them during the brief period when they find elm seeds fit their dietary requirements without worrying too much about the damage they are doing to the trees.

THE TENNESSEE VALLEY AUTHORITY[1]

By Dr. ARTHUR E. MORGAN

CHAIRMAN OF THE TENNESSEE VALLEY AUTHORITY

THE proper way to treat the Tennessee Valley Authority is not as an isolated undertaking, but as an integral part of the whole program of the present administration Most of the great and enduring loyalties of men are loyalties to broad and inclusive generalizations. The dominant religions of the world are examples. They undertake to provide explanations of the purpose and nature of existence and to set up a way of life that will bring about the fulfilment of its greatest possibilities In the Russian program, broad, sweeping conclusions about life and society provide a justification for sustained enthusiasm and for great sacrifice

There are few cravings of men so strong, so persistent and so deep as the craving for an inclusive philosophy, an all-embracing purpose. No leadership which does not provide these can long endure. A promise of obvious and immediate benefit may bring quick and overwhelming response, but for any movement to be long significant, it must undertake to deal with the very nature of things and must offer guidance in the solution of the fundamental problems of living

A long range reading of history will, I think, support this statement. Yet, men are almost universally suspicious of new generalizations After any view of life has won its way to acceptance, it is taken by the mass of the people to be just a part of things as they are, as is the climate. Let any new generalization appear, no matter how logical and inevitable it may be, and it is met with suspicion and incredulity One reason for this is that the average man, while he craves an inclusive philosophy for his life, feels intuitively that he is not equipped to critically appraise the soundness and representativeness of any sweeping generalization, and that he should resist it until it is supported by adequate authority That authority may be an overwhelming emotional appeal, or it may be the support of able men, or it may be evidence of practical capacity on the part of those who make the affirmations. Men do well in refusing to accept a generalization until they have evidence that the person making it has practical ability in the particular field involved, for conclusions about the world and about life are efforts to interpret the nature of things, and should have no claim to authority except as they come from men who have actual acquaintance with and understanding of things, people and events.

But right here we meet with a dilemma. The average man often endeavors to judge the merit of long-range generalizations by temporary and partial results. Sometimes his range of vision is shorter than the necessary periods with which the generalizations deal. To illustrate, let us take the case that is most familiar, the beginning of Christianity. The great Teacher had made sweeping declarations about the nature of human life and about the qualities and attitudes that should characterize the social order. He repeatedly stated that this new order could be the result only of patient search, great commitment and of slow and gradual growth. He repeatedly

[1] Address to the National Academy of Sciences, Massachusetts Institute of Technology, Cambridge, November 20, 1933.

protested that His teachings were being judged, not by their inherent worth, but by "signs and wonders." "The people seek for a sign," He said. He felt that many followed him for the loaves and fishes and not because he proposed a better order of society. Those who presented His philosophy and His personality to the world after His death did not trust to the survival of that philosophy on its merits, but surrounded it with the support of "wonders and miracles."

When we come to appraise the merits of broad-scale conclusions about men and about the social and economic order, it is only with great difficulty that we can weigh and appraise the real knowledge of the nature of things, and the insight, acumen and judgment, which have entered into the making of them. Sometimes we seem compelled to rely upon superficial evidences of practical ability, which may have little to do with the soundness of the generalizations.

I believe that the program of President Franklin D. Roosevelt is more than an assemblage of political and economic expedients. I believe that President Roosevelt has an inclusive social philosophy that has a large degree of clarity, order and integration. To me that philosophy seems to be unusually reasonable, sane and human. It seems to me to be radical in that it gets beyond temporary expedients to elemental issues, and it seems humane and reasonable in its endeavor to bring about necessary changes without violence or undue upheaval which, while establishing a new pattern of society, might do so at tremendous present loss.

Although ours is a young country, our habits of social and economic life are very deeply impressed upon us. To make significant changes in these habits, and to actually lay the basis for a different social and economic order, is no short-time job. Deeply worn paths of habit and action must be cut across with new highways. The period of reconstruction will be troublesome and inconvenient. In Boston here, a few well-planned, broad main highways through the heart of the city would enormously relieve congestion and bring order and economy in local transportation. Yet if that should be undertaken, the temporary inconvenience would be very great, and if those whose vested interests should be interfered with should use that temporary inconvenience to discredit the project, they might be quite successful. In my opinion, a temporary dislocation of things-as-they-are will be an inevitable accompaniment of any significant improvement in our social and economic order. Yet a large number of people will judge the merit of any undertaking solely by its immediate effects. If these people predominate, then the chance for the success of a program will depend, not upon its intrinsic merit, but by the capacity of the leader to produce "signs and wonders" for the benefit of those who judge by immediate and incidental results. I scarcely need list the "signs" which the American people would accept as adequate proof of the authenticity of the President's leadership. Two-dollar wheat, a sudden reduction of unemployment, resumption of dividends, reduction of retail prices —all these would be authentic "signs."

You are wondering by this time what all this has to do with the Tennessee Valley Authority. I believe that my introduction is not irrelevant. A part of the President's program must of necessity be on a national scale. Tariff policy, banking policy, the National Recovery Administration, these and other issues must be dealt with by the nation as a whole. But in the effort to bring social and economic design into our national life, there are many issues which can best be worked out on a limited scale before they are given national application. Many of our problems have regional

variations, and can best be solved through regional interpretation. To provide a limited area in which some of those national issues would have consideration, the President proposed, and the Congress established, the Tennessee Valley Authority.

When I first became acquainted with the Tennessee Valley Authority Bill on its way through Congress, I was greatly disappointed. Here was a great project in social and economic planning, and yet a very limited opportunity was offered for demonstrating the practical competence in handling affairs which to so large a degree is the basis for public confidence. The principal construction work within the area was to be put into other hands, and the Authority itself was at first to have relatively little to do with a construction program I feared that unless the Tennessee Valley Authority should be more deeply engaged with practical matters than the provisions of the bill allowed, its prestige might not increase very rapidly, for there would not be adequate opportunity to demonstrate practical competence. I therefore sought successfully to have the bill changed so as to give the President greater range of choice in deciding what organization should handle the major construction to be undertaken in the region.

When the law was enacted, the President was requested to place the building of the Norris Dam, which was by far the largest item of construction work, in the hands of the Tennessee Valley Authority, rather than in the hands of one of the other departments mentioned in the act. This was done in order to provide practical activities by means of which the Tennessee Valley Authority could become known to the people of the region as a competent administrative organization. With this construction committed to the Tennessee Valley Authority, it became necessary to develop a well-designed administrative organization and to enter vigorously on a construction program.

A little more than five months have elapsed since the directors of the Tennessee Valley Authority were appointed and confirmed by the Senate, the necessary appropriations passed and the corporation organized. As this was a new type of organization under the sun, with a board of three directors who were strangers to each other, and since every point of policy and program and every relation to the administrative processes of government had to be developed, some time necessarily was consumed in getting our bearings. A power program, a program for the development of fertilizers and a general program of planning had to be formulated, as well as an immediate construction program.

An excellent administrative staff has been assembled, after an exceptionally painstaking search, and is well adjusted to its functions. The Norris Dam, the largest construction project of the Tennessee Valley Authority, is well under way, with 1,500 men employed, about as many as will be used at the peak of construction. I believe that less than 5 per cent. of the public works projects of the present administrative program have made as great progress in organization, design and construction. When recently we were unexpectedly asked to undertake the construction of another large dam, this time across the Tennessee River, that additional work was taken on as an almost routine matter, and construction was begun in about one month. The entire administrative staff is now well integrated and well adjusted to its immediate practical job. We have recently informed the Emergency Relief Administration and the new Civil Works Administration, that we can, if needed, quickly expand our staff to supervise the employment of twenty-five thousand or fifty thousand men on emergency projects.

The power program of the Tennessee Valley Authority has been worked out under the direction of David E. Lilienthal, a member of the board, with vigor and dispatch and, I believe, in a masterful manner. The first contract for furnishing power to a municipality has recently been executed, and several hundred miles of transmission line will shortly be under construction.

The fertilizer program of the Tennessee Valley Authority, which was explicitly provided for in the law, also is well under way, directed by my colleague, Dr. H. A. Morgan, with an excellent research staff. Pilot plants are being designed and will shortly be under construction.

During this period about one hundred and ten thousand applications for positions have been received. About sixty thousand of these have been classified and rated so that the best prospects can be quickly located in any field. Another fifty thousand applicants will have been given examinations and will have been classified and rated by mid-January.

A number of acute issues have been met and faced. For instance, there is the matter of patronage and the spoils system. The Tennessee Valley Authority law provides that all appointments shall be made on merit and not for political considerations. It is my personal opinion that the President approves this provision. Yet the issue of spoils and patronage has been met very acutely. The record of the Tennessee Valley Authority on that issue should, I believe, give confidence to those who hold that public servants should be chosen for their merits and not because of political influence.

Those who are administering the Tennessee Valley Authority have, I believe, given evidence that they have had some contact with realities and some acquaintance with public and business administration. With that demonstration, we hope that we may achieve some other classification than the Washingtonian designation of "perfesser" in our effort to work out a program of social and economic planning in cooperation with the people of the Tennessee River region.

What should be the aim of such planning? Considering the Tennessee River region, not as having peculiar and different problems, but as being representative of many regions in America, what do we find? We have in this region a population of old American stock with a large proportion of persons of good intelligence. A large industrialist, who has plants in various parts of the country, tells me that nowhere else does he find so large a proportion of his working force made up of men who can understand and master technical processes and problems. The working forces on our construction jobs are of a higher order than we commonly find in other parts of the country. About twice as many people are engaged in agriculture as are necessary to till the soil. Good roads have opened up the region and made accessible areas that formerly were remote and isolated.

Mineral resources in this region are exceptionally abundant and highly diversified. There are large deposits of coal. Much of the hardwood timber has been cut and exported from the area as raw material, but there is still an adequate supply for local industries which will produce finished goods. Climatically, this is one of the favored regions of America. The few localities, like Asheville, which have become known as fall and spring resorts, are but typical of large areas. The summers are not too hot, or the winters too cold. There is an abundant water supply, in many localities exceptionally free from iron, lime or other minerals and therefore suitable for exacting manufacturing processes. Lastly, there is a great reservoir of po-

tential power. About 3,000,000 kilowatts are awaiting development, at unit costs that in many cases are very favorable.

We seem to have here all the factors for a prosperous, progressive community, and yet we find production and consumption on a low level. The Tennessee Valley Authority area varies greatly in different parts. In the northeast portion are localities where, until ten years ago, many young men and women had never seen a colored person. On the other hand, along the southern boundary of the area are counties where a quarter to a half of the population is colored The Tennessee River region contains some notable, progressive and well-kept farm communities and some prosperous cities.

Generalizations must not be carried too far in so varied a region, yet it is true in general that only a very small part of the potential productiveness is being realized. One study of a mountain county in Kentucky indicated that the average cash income of a mountain farm is $45 a year. A study of 200 mountain farms in Western North Carolina, distributed in four localities, indicated that the average cash income, after paying fixed charges, such as taxes and fertilizer, is $86 a year. A large part of the farms of the region have a cash income of less than $250 a year after taxes are paid.

Here we have the picture—a vigorous and intelligent people near the center of the American population, abundant natural resources, a great reservoir of cheap power, a fine climate—but a low level of production and consumption and relatively little effective social and economic organization. The region is not yet heavily committed to mass production and economically is still in flux. Only a quarter of the population lives in towns of 2,500 or more. To a large degree in the past, the industry of the region has consisted of the exploitation of natural resources, to be exported as raw materials. More recently it has turned to the exploitation of cheap labor.

This is the region the President has selected for a case in social and economic planning. Given a magic wand, these factors could be turned into prosperity, well-being and wholesome culture. But magic wands are not quoted on the market. The President, I believe, sees this project as one of seeking the cooperation of the region in eliminating the grossest wastes and in creating design, order and organization for releasing the creative capacities of the people and for the best use of the natural resources of the region. Let us outline some of the major wastes, present and potential, which reduce well-being.

First, there is soil erosion. In the rolling lands of the Southern states this issue is far more critical than in the North and West. Millions of acres have been entirely destroyed for agricultural use. Deep gullies extend every year further into the fields, and each year the hillsides of bare clay, from which all loam has washed away, increase in area. Unless this process can be stopped, the human culture of considerable regions will disappear. When a large part of an area is destroyed for agriculture, the remainder can scarcely afford the necessary taxes for schools, and the better families move away. After that the destruction is accelerated.

There are several possible methods for stopping this waste. Terrace farming and careful management of the soil may reduce the erosion to less than a quarter of its rate on badly managed farms. Crops which keep a sod over winter can be planted instead of corn, for which ground is plowed in the fall and exposed to washing all winter. Certain new pasture and forage crops are very promising. The hilliest lands should be taken

out of cultivation and planted to forest. Finally, the laws of land ownership should be changed so that men shall not be allowed to own and occupy land unless they will manage it in the interest of a permanent agriculture. Such a legal change would constitute one element of a social revolution.

Then there is the great waste in the electric power situation. Men have a few basic needs which must be supplied as part of a civilized environment. One of these is an abundant supply of pure water. Other basic services are transportation, communication and power. We shall steadily approach the time when these services are so cheaply and abundantly supplied that they fall into the background as requiring but little of our thought.

At the present time electric power is one of the live issues of social planning. Every one is familiar with the disclosures of the Federal Trade Commission, of the wide-spread endeavor by secret and open propaganda to control the thinking of the nation on this issue. In a few cases where unusual indiscretion has opened the scene to the public, as in the case of the once very honorable Mr. Insull, we can see what the industry is like on the inside.

The Tennessee Valley Authority is interested in the electric power issue on several counts. First, if a case of public ownership and operation can be established, with fully open and comparable cost accounts and records, we may be provided with a "yardstick" by which we may discover what electric power actually ought to cost. The private utilities, if they are sincere in their expressed belief of the superiority of private ownership and operation, should welcome such an example.

It is not only the private utilities that will be provided with a "yardstick." Public ownership will be on trial. One of the greatest diseases of our national life is the spoils system in public office. Unless it can be overcome it threatens the very life of our democracy. If the public generation and distribution of power can be kept free and clean from the spoils system, there seems to me no reason why it can not be economical and effective. If government-owned power can not keep free from this incubus of political patronage, we had better discover that fact on a small scale, before we are plunged into some nation-wide scheme of public ownership.

Another object of the Tennessee Valley Authority is to make this region and the country as a whole more fully aware of the vast possibilities of electric power for enlarging the freedom and scope of modern life in the home and on the farm. This can only come with cheap power, from which all speculation and exploitation have been removed. The electric power business is one of the simpler industries of our country. It does not compare in complexity with the shoe industry, the automobile industry or the railroad industry. No vast tribute should be paid for management and financing. Brought down to its simpler necessities, electric power should be a universal convenience, supplied as city water supplies usually are, on a basis of service and not of commercial exploitation.

Lastly, the economy of electric power in the Tennessee Valley area will depend much on large-scale developments that are designed and operated as single integrated systems. The entire Tennessee River system, with its thousands of miles of streams, should be under one control and ownership, which means government ownership. An example will illustrate: all along the Tennessee River power plants can be installed with a total fall of about five hundred feet. But these are "run-of-the-river plants." That is, they provide little storage and the water must be used as it flows. At Muscle Shoals, for instance, the capacity

during high water in winter may be 600,000 kilowatts, whereas the low water of a dry summer may generate only 40,000 kilowatts. The maximum capacity at high water is fifteen times the minimum capacity at low water. Yet it is only the "prime power," or power that is nearly always available, that has much value. Now, up river on one of the main branches of the Tennessee is a power project of another sort. A high dam will produce vast storage capacity, great enough, in fact, to store a year's supply of the stream. There has been a project on foot to build a great industrial plant at this up-stream site, using the power for manufacturing purposes. The control of flow would be determined by the orders received by that one plant and by its need for power. It might be using much power, and therefore releasing much water, during the high water of winter, when there is already a superabundance of water in the river below. During the summer the plant might be shut down and water might be stored above when it is most needed below.

If the entire system should be owned and operated as one, the situaton would be very different. The entire system would be interconnected by transmission lines. During the high water of winter the upper plant would be shut down and the water stored in the reservoir. Abundant power would be available from the river plants below where no storage is available, and where the water must be used as it comes. Then, during the summer, when the river is low and electric power scarce and most valuable, the upper plant would be operated. Not only would a large amount of power be available there, if the whole year's storage were to be used in these months, but all the water used in the plant above would have to pass through each of the plants below, all the way to the mouth of the Tennessee. By such united operation probably twice as much "prime power" or dependable power could be generated for a given investment, or, in other words, the power would cost half as much per kilowatt hour.

Private utility men say that they would get the same result by trading power among themselves. That, however, does not answer the question. In the original installation of an up-river power plant, the investment which is justified in providing storage will be determined by whether an income will be produced by the water which is released from the reservoir, as it goes through other power plants down the river. For instance, the Norris Dam now being built by the government on Clinch River is made higher, and the reservoir is made larger, than would be justified by the power possibilities for the dam itself. The Norris Dam plant will be worth more as a regulator for Muscle Shoals than for the power it could generate at its own plant treated independently. The water going through Norris Dam plant will be worth twice as much at the plants below as it is at its own plant. An investment justified by the whole system would not be justified for an independent plant.

Down stream for the Norris Dam is a private power development on the Tennessee River—the Hales Bar Dam and Power Plant. The value of that private plant will be doubled by the building of Norris Dam at public expense. Only by a single organized system of water power plants for the whole Tennessee River system can the full economy be realized. With that organization, water power may cost less than half what it would if the various units should be developed independently by private companies. Water power is to have stiff competition from steam and Diesel engines. If the Tennessee River region is to realize its possibilities in water

power it can not afford to throw away this economy.

Let us take another need for social and economic planning in another field —that of county government. The county organization of this region was determined during the early days, a century or more ago, when there were few roads, and when men traveled by horseback up the creeks. The court-houses would be half a day's trip from the county borders. With modern roads and automobiles a man travels as far in half an hour as one did then in half a day. A study in some of these county court-houses discloses that in some of them all the work of the county officials can be done in one half day a week. A consolidation of counties into perhaps one sixth as many might more than cut in two the cost of local government and greatly improve its quality.

For a moment consider industry. Twice as many men are engaged in agriculture in this region as are needed to produce the crops. A balance of industry and agriculture may be very helpful. But this program has its dangers. In a large city, if a man is discharged from one job, or if his pay is reduced, he may find another. In a small, one-industry town, with the workers living on nearby farms or on small tracts, they may become virtually serfs and unable to protest against any policy of the management. A company with half a dozen plants in as many towns may close any one at its pleasure if it wishes to enforce a policy toward labor. In many of these one-industry towns only salaried managers are present, and all the profits go to far-off large cities.

Is it possible to bring about a balance of industry and agriculture and preserve the vitality of the small communities of this region, so much favored by the people, and yet prevent economic exploitation?

Such are a few of the many issues facing the Tennessee Valley Authority. There are other issues—the need for a forest policy, the possibility of developing cooperatives in selling and buying, the possibility of furnishing cooperative service to small enterprises and merchants in accounting, business management and other technical phases of work, so that the small proprietor may have approximately as good administrative advice as the large corporation.

There is the problem of vocational guidance. With a great overproduction in the standard professions, such as law, medicine, architecture, engineering and education, is it not possible to direct young men and women from these overcrowded professions to other fields where the work of the world is done badly. We might mention such new fields as the management of publicly owned utilities, the organization of groups of counties and cities for police protection, the development of planned and creative recreation facilities for small communities, the development of cooperative services for small proprietors, the development of community health services, the better feeding of unmarried working people in boarding houses. Much of the work of the world is being very badly done. Any badly done job is a call to a new or to a better calling. Can we relieve the crowding into old callings in our region by opening the way to new ones?

There are other fields of interest. The mineral resources of this region are abundant, but very often in small deposits. Is it possible to develop local mining projects, cooperatively supplied with management? There are great possibilities for developing the special skills and aptitudes of the region for the production of quality goods, as has been done in France and Vienna. America needs such an area not committed to mass production, where individuality in industry can satisfy our craving to escape monotony.

Mass production will also have its place. How to unite basic industries, so that the by-products of one become the raw material of another; how to choose locations with reference to power supply, raw materials, transportation and market, requires an integration of research seldom available to private industry. Such problems are in the picture.

But all this does not complete the idea of President Roosevelt. Increase of production and of total wealth does not necessarily mean an increase of general well-being. During recent years we have heard much about the new "economy of surplus" as though it were the first time in history that such an economy had occurred? Great surplus of men and goods is far from being new. Over and over again it has occurred. Almost our earliest recorded history is of vast economic and human surplus in Egypt. It might have been used to develop housing, sanitation, education, research and general culture. It was used to produce the most terrible servitude and some enormous piles of stone. That historic type has continued through the ages. It has not been absent from America. The past decade has not been free from it.

To escape from that use of surplus so that productive capacity shall produce well-being, that is the aim of President Roosevelt. I think a better phrase could be used to describe his purpose. He has spoken of a "new deal." That means that the cards shall be shuffled again, but that the same old process shall be repeated, with perhaps other persons holding the good hands.

What we need is not a new deal, but a new game. We need a game which, when played according to its own rules, will bring a different kind of results. The President may have been imperfect in his phrase, but he is right in his purpose. It is that the moving spirit of our social and industrial life shall be neighborliness and not the predatory impulse, that we shall guide our social and economic affairs by a realization of their total effects, to the neighbors and to the future, as well as to ourselves and to the present. Whether we are dealing with soil erosion or electric power or local government or industrial distribution, that is the goal.

How can we do that in the Tennessee Valley? The aim can be held in general, but its execution gets down to a series of particular cases—to hydraulic studies for power plants, to chemical processes of manufacture, to educational methods, to principles of sociology and of economics, to researches in government, to studies in industrial organization, production and distribution. In such an undertaking the Tennessee Valley Authority can be but a clearing house for the experience, the judgment and the insight of such men as I am addressing here to-night.

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MEASUREMENTS OF PERSONALITY

By Dr. MARK A. MAY

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THE practical aim of all science is to predict and control the activities with which it deals. Astronomers can predict with extreme accuracy the appearance of eclipses, comets and meteors, the rise and the fall of tides and other more complicated actions of the heavenly bodies. Engineers can forecast accurately the strength of bridges, the safety of high buildings and hundreds of other practical events. In fact, the greatest achievements of modern science may be summed up in two words—prediction and control.

In the realm of human relations science has been less successful in making accurate predictions. The laws that govern human behavior are much more intricate than those that govern the stars and planets. There is in the affairs of men that so-called "personal equation" which upsets all calculations. It is easy to predict and control the behavior of mechanical men, which scientists have recently built, because the laws governing their actions are understood. Whether or not science will ever be able to predict human behavior with precision and accuracy is still an open question. Much depends on the extent to which it can be measured. There can be no accurate predictions without measurement.

Personality can not be measured by any simple yardstick, foot rule or thermometer. It has a great many different aspects and dimensions, each of which requires a different measuring instrument. Science has, therefore, not achieved a satisfactory measure of it. The greatest achievement of science to date is the invention of useful methods of measuring different aspects of personality.

I shall review these methods briefly. Suppose we have before us now our old friend John Doe. How may we discover what sort of a person John really is? Is he strong, magnetic, reliable, talented, courageous, honest and kind? Or is he weak, repulsive, cruel, cowardly, dull and deceitful? While these are only a few of the things we wish to know about him, they represent the kinds of questions we ask.

There are six different ways of finding out something about John Doe. Each represents a scientific approach to the study of his personality. First of all, we study his record. John, like every one of us, has left behind him footprints on the sands of time. These are his letters and other writings, his school grades, written applications for a gas meter or automobile license, registration for voting, and so on. His photograph will also tell you something about him, but just what it tells has not been scientifically determined. It is quite possible, and in fact easy, to find out a great deal about John Doe without ever seeing him or consulting others about him.

Second, ask those who know him. Members of his family, his teachers, his employer or his employees, his creditors, his pastor or his lawyer (if he has one), his neighbors and friends, all have very definite impressions concerning what kind of a fellow he is. Furthermore, most of them are willing to talk about him. If you approach them right, they will go so far as to rate him high, low or

average on many character and personality traits. The rating method is one of the most common devices for the scientific study of personality. Thousands of rating scales and techniques have been devised and there are now on record ratings of hundreds of thousands of individuals. But ratings are not true measures, they are at best only carefully and systematically recorded impressions and opinions. What they really measure, if anything, is John Doe's reputation, which is only one part of his personality.

Third, observe him. Three kinds of observations will be useful. First, note his physical appearance, second, his expressive movements, and third, his actual conduct. If John Doe is a little fellow, far below the average in size, it is likely that he has developed personality traits which compensate for his physique. If, on the other hand, he is a big fellow, his personality will probably be quite different. The German scientist, Kretschmer, has studied the physical build of many insane persons and finds a close parallel between body types and types of insanity. Many attempts have been made to relate facial features to personality. But these measures have not been scientifically verified.

More significant are the expressive movements. John Doe expresses his true personality in the manner and form of his actions. He has a certain gait which is all his own. The same is true of his handwriting, his style of language, manner of dress, his gestures and other movements which are more or less unconscious and involuntary. Thus each of us has his own peculiar style and form which betray his inner self to the trained eye of the scientific observer. Hans Gross, the German criminologist, developed the theory that every criminal has his own individual style or form of committing a crime, and always leaves behind him certain clues by which he can be identified.

The quality of the human voice also expresses personality. An English psychologist, Professor T. H. Pear, conducted an interesting experiment on what he called the radio-personality. He arranged for nine mystery speakers to broadcast the same speech. The radio audience attempted to guess the age, sex, occupation, locality of birth and other characteristics of each speaker. The results were surprisingly accurate, indicating that the quality of the speaker's voice betrays, in some degree at least, not only his sex, age and occupation but many other personality traits. One of the speakers was a detective-sergeant who was frequently described as "a robust man of heavy build, stout and burly."

Going back to our friend John Doe, one of the best ways of finding out what kind of a person he is is to observe his conduct. How does he behave at home with his family or when the family is not around? How does he behave on the street, in his office, at social gatherings and in other walks of life? To really understand him, we must observe not only the manner in which he does these things, but what he actually accomplishes. What he does makes him what he is. But it is very difficult to record scientifically observations of human conduct. It looks easy, but try it and you will find that you can not observe and record one tenth, no not one one hundredth, of all the things John Doe does, unless you do it in a very general way. Science is just beginning to find how to make accurate observations of human behavior. It is also difficult to determine which of John Doe's actions are worth recording. Some of his acts are more significant than others. Some psychoanalysts have suggested that one significant set of acts are slips of the tongue, pen or fingers. These slips are involuntary movements which are supposed to be especially symptomatic of the true personality.

The fourth way of studying John Doe's personality is to interview him. If you can establish friendly relations with him either as a scientist in quest of knowledge or as his physician, lawyer or pastor, he will submit to direct questioning and will tell you a great many things about himself. Your task is to select the questions that will bring out the aspects of his personality in which you are for the moment interested. But if he will not submit to direct questioning you will have to employ methods that are more subtle and indirect. The usual procedure is to get him talking about anything at all, and, if he is like most persons, he will eventually get around to telling you about himself. The interview is the method most commonly used by employers in sizing up the personalities of prospective employees; it is also the method used by psychiatrists in diagnosing the personalities of the insane and the mentally maladjusted.

The fifth method is psychological tests. Psychological tests represent the most significant efforts to measure personality. A test is essentially a measuring device. There are a great many different kinds of tests, each intended to measure a different phase or aspect of personality. The best are known as intelligence tests. There are also tests of special abilities, talents and aptitudes. There are tests of instincts and emotions, of social adjustments, of educational achievement, of moral knowledge and conduct, including such types of conduct as honesty, cooperation, generosity, courage, will-power, self-control and the like. There are also tests of appreciation of art, music and literature, tests of likes and dislikes; tests of social attitudes, opinions and beliefs; tests of interests in occupations, games and sports. All these are efforts to measure various aspects of the personality.

There is in addition a special kind of a test known as a general personality test. This test, which exists in various forms, is really a questionnaire which inquires into symptoms of personal adjustment or maladjustment. It is a sampler of symptoms. Some of the questions are: Do you day dream frequently? Do you blush very often? Are your feelings easily hurt? Do you make new friends easily? Do you haggle over prices with salesmen? Do you hesitate to borrow things from your neighbor? The theory is that while no single question taken by itself is significant, yet a large number of them reveal characteristic modes of adjustment which are symptomatic of normal or abnormal personality.

The sixth and final method of studying personality is by experiment. Since the laboratory is the workshop of the scientist, personality must eventually come under instruments of precise measurement. To secure scientific data on John Doe he must submit to experimentation. But there is a popular prejudice against experimenting on human beings. Such prejudices are usually based on detective stories and movies and are quite without foundation in fact. Most psychological experiments are 100 per cent. harmless, most of them are interesting to the subject and some of them are good fun. Laboratories are now equipped with instruments for measuring not only the physical characteristics of human subjects but also their mental and physical functions as well. Many of these functions, if not all, are definitely related to personality. For example, the fluids of the body, including the blood, the saliva, the urine, the spinal fluids, and others, are so chemically constituted that changes in their compositions are frequently accompanied by changes in behavior. In fact, some scientists hold that in the electrical and chemical phenomena of the body lies the solution to the problem of the prediction and control of conduct.

All these efforts to study, estimate and measure the human personality have

practical advantages. Two of the greatest social problems now confronting civilization are crime and insanity, both of which are in the final analysis problems of personality. There are also the problems of divorce, of graft, of racketeering, of suicide, and many others which depend for their final solution on an understanding of human nature.

We are all speculating in "futures," whether we are buying distillery stocks or German marks or wheat and cotton The future is a speculation because of the uncertainty of the "personal equation" in all human affairs. It is this unpredictable human element that causes runs on banks, stock market crashes, labor strikes, frozen credits, and disturbs the whole economic order. There is no doubt that during the depression the psychological factor has played an important part. It is the hope of science that this human element may be analyzed, understood and measured—and finally predicted and controlled.

POETRY OF THE ROCKS

By Dr. R. S. BASSLER

CURATOR OF GEOLOGY, U. S NATIONAL MUSEUM

MAN'S natural curiosity about his earthly habitation has ever made earth science, geology, the science of the rocks, a subject of keen interest to him. What has happened on the earth down through the ages and what has life, especially man, had to do with it? These are questions which thinkers as far back as Pythagoras and Aristotle have tried to answer.

Geology has grown to be perhaps the most comprehensive of the sciences, for it deals with the story of the earth and its inhabitants from the time our planet was a fiery mass revolving in its charted course through the heavens and subject only to physical laws, down to the present when life has become such a predominant factor. If one has a limited amount of time to obtain a general knowledge of science, geology will surely give a more comprehensive view than one of the more specialized branches.

That there is no royal road to learning and that only persistent, painstaking effort will lead to the acquisition of knowledge has been pointed out time and again. However, education has long sought for a more vital approach to learning than the memory method. Pictures, both moving and still, are now widely employed in the teaching of science, for it is recognized that we learn more readily by looking at things than by memorizing facts about them.

The principle holds still better if the object itself can be viewed. In geology the visual method of learning is especially applicable because every mountainside or stream valley reveals chapters of earth history often quite puzzling to the layman but usually plainly visible to the student of nature.

Still another method of impressing the facts of science is through the emotions, particularly through the appreciation of literature or music. Long ago Herbert Spencer pointed out in his "Essays" that not only does science underlie sculpture, painting, music and poetry, but that science itself is poetic. He further has written that science opens up realms of poetry where to the unscientific all is blank, and he quotes Hugh Miller's books on geology as scientific works inciting poetry.

Much of the poetry of nature which has endured has been written by students who have described their impressions with such care that they are scien-

tifically correct, even though the underlying principles may not have been understood. The geologist is seldom a poet and the poet rarely has an appreciation of geology, yet often they evidence a mutual understanding. Byron expresses the feelings of the appreciative geologist when he writes:

To sit on rocks—to muse o'er flood and fell—
To slowly trace the forest's shady scene,
Where things that own not Man's dominion dwell,
And mortal foot hath ne'er or rarely been;
To climb the trackless mountain all unseen,
With the wild flock that never needs a fold;
Alone o'er steeps and foaming falls to lean;
This is not Solitude—'tis but to hold
Converse with Nature's charms, and view her stores unrolled.

The first chapter of Genesis, that great poem from the pen of the inspired philosophers, is an abridged volume of geologic history. Its seven days or eons of time so closely parallel the great eras of earth history as determined from the evidence of the rocks that the old-time idea of the conflict between religion and science based on an erroneous conception of the Biblical account should be discarded once for all.

Students of geology can recognize in this account the story of evolution which parallels that presented in the rocks, namely the change of the earth itself from the first great void to the present arrangement of land and sea, then the upward progression of life from the first most primitive plants to the simplest marine animals, and on to the more complicated land vertebrates, finally culminating in man.

The story of evolution is succinctly outlined in the introductory stanza of Carruth's "Each in His Own Tongue," a poem in which the relation of the Creator to the beautiful things of life is feelingly portrayed.

A Fire-Mist and a planet—
A crystal and a cell—
A jelly-fish and a saurian,
And caves where the cave-men dwell;
Then a sense of law and beauty,
And a face turned from the clod—
Some call it Evolution,
And others call it God.

In both the Biblical and scientific accounts of the earth's origin, it is evident that eons of time had elapsed before man appeared upon its surface. During this long interval physical processes in the form of wind, water and temperature were actively at work in some places slowly leveling mountains, in others cutting valleys only to be later filled with sediments, and in other ways modifying the face of the earth in preparation, as we sometimes boastfully say, for man's coming.

All of these processes are described under the general term of weathering, but perhaps the most far-reaching of them is the wind. A logical discussion of this phase of earth history, termed "physical geology," will start with the work of the wind and continue with that of the rain, which, sinking into the earth, forms the ground water, or running off the surface as streams finally enters its original source, the ocean. In this talk only the physical elements and their work concerned in geologic history will be discussed.

The geologic effect of the winds is both constructive and destructive. They control weather conditions, particularly rainfall, which in turn through the streams and by solution, weathers away or breaks down the land surface. Winds also create ocean waves and currents in the sea and thus increase their geologic significance both by wearing away the rocks at one place and by depositing the eroded material elsewhere.

The beneficent west wind, wafting the warm, moisture-bearing clouds to the British Isles and making life pleasurable there, in a latitude as far north as our own Labrador, forms the subject of Lord Tennyson's song of "Sweet and Low" from "The Princess."

Sweet and low, sweet and low,
  Wind of the western sea,
Low, low, breathe and blow,
  Wind of the western sea!
Over the rolling waters go,
Come from the dying moon, and blow,
  Blow him again to me:
While my little one, while my pretty one, sleeps.

On the other hand, the work of the wind and the destructive forces set free by its action are dramatically portrayed by Austin Dobson in his "Song of the Sea Wind." Here he graphically describes its cutting force on the land, then its erosive power along the shore line and its explosive ability from air compressed in the sea caves and finally, in the closing stanza, its subsidence and reckoning:

How it sings, sings, sings,
  Blowing sharply from the sea-line,
With an edge of salt that stings;
  How it laughs aloud, and passes
  As it cuts the close cliff-grasses;
    How it sings again, and whistles
    As it shakes the stout sea-thistles—
      How it sings!

How it roars, roars, roars,
  In the iron under-caverns,
In the hollows of the shores;
  How it roars anew, and thunders,
As the strong hull splits and sunders:
  And the spent ship, tempest driven,
  On the reef lies rent and riven—
      How it roars!

How it wails, wails, wails,
  In the tangle of the wreckage,
In the flapping of the sails;
  How it sobs away, subsiding,
Like a tired child, after chiding;
  And across the ground-swell rolling,
You can hear the bell-buoy tolling—
  How it wails!

In his poem, "Winter," Robert Burns expresses his appreciation of the raw snowy days with their fierce blasts and he seems to derive real pleasure from a comparison of his own sad fate with them. Others of his poems indicate how he was influenced by the geologic background of his home in the Scottish Highlands where the prevailing hard granites and other igneous rocks weather into a countryside with an equally harsh environment.

The wintry west extends his blast,
  And hail and rain does blaw;
Or the stormy north sends driven forth
  The blinding sleet and snaw:
Wild-tumbling brown, the burn come down,
  And roars frae bank to brae:
While bird and beast in covert rest,
  And pass the heartless day.

Weather conditions brought about by the winds often result in rain which, absorbed upon reaching the earth, becomes ground water. Besides supplying the water for human activities and furnishing moisture for plants, ground water in limestone regions works insidiously under the surface, dissolving away the rocks, forming caves and otherwise eroding the land. Rain and ground water were poetically appreciated long ago in the poem called "Drinking" by the great lyric poet. Anacreon, who concludes his lines with a question still quite timely:

The thirsty earth soaks up the rain,
And drinks, and gapes for drink again,
The plants suck in the earth, and are
With constant drinking fresh and fair,
The sea itself—which one would think
Should have but little need of drink—
Drinks ten thousand rivers up,
So filled that they o'erflow the cup.
The busy sun—and one would guess
By's drunken fiery face no less—
Drinks up the sea, and when he's done,
The moon and stars drink up the sun:
They drink and dance by their own light;
They drink and revel all the night.
Nothing in nature's sober found,
But an eternal health goes round.
Fill up the bowl then, fill it high,
Fill up the glasses there; for why
Should every creature drink but I;
Why, man of morals, tell me why?

Streams are very lifelike in their actions. They go through the various phases of life, youth, maturity and old age and often exhibit real human emotions. A youthful stream with few or no tributaries will courageously attack the

land of its birth. Its life work, the task of breaking down the rocks in its course, is before it. Upon reaching maturity, it is found to have divided into many branches and to have cut the former land surface into a series of hills and valleys. When old age arrives, even the hills have been eroded away and the stream, tired from its exertions, no longer supports a family of tributaries, but now meanders sluggishly over the low plain it has formed from the highland of its youth. The Colorado, in the Grand Canyon, is a vigorous youngster, but Tennyson's "Brook" is a baby stream with all its childish ways.

> I chatter over stony ways
> In little sharps and trebles;
> I bubble into eddying bays,
> I babble on the pebbles.

"As old as the hills" is an oft-repeated simile, but it should read "as old as the streams," for they precede the hills and cause their formation. In maturity, stream erosion is taking its full toll of the hills, or as the poet describes it:

> The hills are shadows, and they flow
> From form to form, and nothing stands;
> They melt like mist, the solid lands
> Like clouds they shape themselves and go.

In old age the wear and tear of the stream's life is at an end and peace and rest are at hand. Robert Burns' "Sweet Afton" is such a stream:

> Flow gently, sweet Afton, among thy green braes,
> Flow gently, I'll sing thee a song in thy praise;
> My Mary's asleep by thy murmuring stream,
> Flow gently, sweet Afton, disturb not her dream.

The ocean, the ultimate destination of old-age streams as well as all other water-courses, is their birthplace and final resting place. Covering three-quarters of the globe, the ocean serves as the great stabilizer of climate. The sun's unfailing energy has, of course, caused the remarkable constancy of the earth's climate these hundreds of millions of years, but the ocean, by storing up excess warmth and distributing it through currents into the higher latitudes, has played a large part in equalizing temperature.

The more obvious effects of the ocean are seen in the gnawing action of the waves along certain sections of the seashores and in the depositing at other places of the eroded material as sandbars and other well-known near-shore features. The theme of the waves breaking on a rocky shore is used by Tennyson in his well-known poem, "Break, Break, Break":

> Break, break, break,
> On thy cold grey stones, O sea!
> And I would that my tongue could utter
> The thoughts that arise in me.

Probably the most feeling poem touching upon the phenomena of the sea is Tennyson's "Crossing the Bar," written in the latter part of his life, a poem which may very well conclude this discussion of poetry in rocks.

> Sunset and evening star,
> And one clear call for me!
> And may there be no moaning of the bar,
> When I put out to sea,
> But such a tide as moving seems asleep,
> Too full for sound and foam,
> When that which draw from out the boundless deep
> Turns again home.
> Twilight and evening bell,
> And after that the dark!
> And may there be no sadness of farewell,
> When I embark;
>
> For tho' from out our bourne of Time and Place
> The flood may bear me far,
> I hope to see my Pilot face to face
> When I have crost the bar.

EXPLORING FOR PLANTS IN THE SOUTHEASTERN STATES

By Dr EDGAR T WHERRY

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ONE of the most pressing tasks of the plant geographer is to ascertain as fully as practicable the present distribution of the various kinds of plants over the surface of the earth before civilized man succeeds in destroying all natural habitats and exterminating their occupants While many manuals and floras give in a general way the ranges of such species as occur within the areas covered accurate distributional data are at hand for very few The lack of such information is especially serious in the case of plants endemic to the southeastern United States where there has been so little collecting that the range of even conspicuous objects like the pitcher plants is but imperfectly reflected by specimens in herbaria. I was accordingly especially glad to be invited by Mr Louis Burk the well known Philadelphia horticulturist to obtain for him a complete collection of the species and varieties of *Sarracenia* in the summer of 1932 Not only would such a trip make it possible to fill in many gaps in the recorded ranges of these plants but also there would be a chance to study in the field undescribed ones as to which more or less unsatisfactory data were at hand

Late in June I drove to Washington, D C and was fortunate in having Mr James E Benedict Jr join me for the trip Continuing southward on U S Route 1 our first stopping point was Raleigh North Carolina where we called on Professor Bertram W Wells. He not only furnished us information as to pitcher plant localities in the southern part of that state but also showed us a tiny meadow not far from the city where by good fortune a few pitcher plants still survived the encroachments of agriculture Two species were represented, the wide-spread yellow pitcher plant (*S flava*) and a relative of the side-saddle pitcher plant (*S purpurea*) which we especially wished to study In his Autikon Botanikon published in 1840, Rafinesque had pointed out what he considered specific differences between the northern and southern representatives of this species and had named the southern one *S venosa*, but his work has been ignored by all subsequent students of these plants At this locality its aspect was certainly quite unlike that of the familiar pitcher plant of New England and the Great Lakes region, and we felt disposed to accept Rafinesque s interpretation of it, but other occurrences seen in the course of the trip indicated the two to intergrade too much to be maintained as independent species. Additional data as to pitcher plant localities were obtained from Professor William C Coker at Chapel Hill and we set out for central Georgia. At Macon we were joined by Dr Charles C Harrold for a two-day trip on the coastal plain of the state

As we traveled southeast pitcher-plants began to appear in the swamps in the vicinity of Swainsboro; these comprised not only the tall and conspicuous *Sarracenia flava*, but also the diminutive hooded (*S minor*) and parrot pitcher plant (*S psittacina*) Michaux had reported the latter from "Augusta, Georgia to Florida," and desiring to obtain roots from as far north as possible, we kept searching for it in one county after another, but the most northern colony to

be found lay 10 miles south of Millen and thus fully 50 miles south of Augusta Several rooted clumps were collected, packed in wet moss, carried with us until we could find a state inspector and get them certified as pest-free, and then shipped home. Some of these were planted outdoors in a wild-life preserve controlled by Mr. Burk in southern New Jersey, where they have survived the first winter, at least The remainder were held in a cool greenhouse, and bloomed freely during early spring

Pitcher-plants were, however, not the only thing to claim our attention in this part of the country. We planned to make an effort to rescue a native tree which is on the verge of extinction This plant, discovered by Stephen Elliott in the early 1800's and named in his honor *Elliottia* by Muhlenberg, is a primitive member of the heath family The genus is monotypic, being represented by the single species *E. racemosa*, and its nearest relative is the genus *Tripetaleia* of Japan. These are evidently relics of the late Cretaceous and early Tertiary floras which spread widely over northern lands, but have been restricted by subsequent geological events, especially the Pleistocene glaciation, to remote isolated areas

Elliottia is a small tree, attaining a height of about 15 feet and a trunk diameter of 2 or 3 inches It spreads by rootstocks into colonies of a score or two of individuals, and about the end of June produces attractive large panicles of small white delicately scented flowers. These attract various sorts of bees, which carry pollen from flower to flower; as a rule, however, no fertilization occurs, and the ovaries soon drop from the pedicels Evidently individual plants are sterile to their own pollen, and as each of the 5 or 6 known colonies is apparently the result of vegetative propagation from a single seedling, this sterility extends throughout Before the coming of the white man colonies must have grown close enough together for pollen to be borne by insects from one to another, and seed was sometimes produced. Clearing the land for agriculture and burning over the woods destroyed so many, however, that this no longer occurs, and the seed of the species is actually unknown to science.

FIG. 1. OUR SHOWIEST SPECIES OF PITCHER-PLANT IS *S. DRUMMONDII* WITH THE UPPER PART OF THE LEAVES WHITE, VEINED WITH GREEN AND RED. THIS VIEW WAS TAKEN AT ITS NORTHERNMOST KNOWN STATION, NEAR AMERICUS, GEORGIA.

The current practise in that region of burning the low-growing vegetation every year or two causes the *Elliottia*, like many other plants which, when undisturbed, have an arborescent habit, to send up numerous small shoots from their woody underground parts, and thus produce shrubby thickets. These often become so dense that reproduction of the longleaf pine and other valuable trees is prevented, until another fire destroys the brush to which the preceding one gave rise, which has led to the curious idea held in many circles that frequent burning is natural and desirable. No doubt the great pine forests of the coastal plain got started in the first place when particularly severe fires destroyed whatever deciduous climax forest formerly occupied the areas; but the infrequency of charred rings in stumps and of charcoal layers in peat deposits shows that before the white man came fires occurred only at intervals of many years. Unless and until the present frequency of fires shall be reduced to that of primeval times by protective measures and by education, all but the most vigorous and aggressive of the native plants of that region are doomed to extinction in the near future, and it seems idle to talk about "reforesting the south."

Because, then, of the impending disappearance from native habitats of this relic of past geologic times, *Elliottia*, all possible efforts to get it into cultivation are worth while. With this in view, Mr Harry W Trudell and I had twice before visited this region and had located certain of the remaining colonies of the tree, in part through directions kindly furnished by Dr Roland M. Harper (who, I should state at this point, disagrees with me completely as to the fire situation). Both times we had found but a single colony in bloom, the others having been seriously damaged by the fires of those years. On the present trip, however, conditions were more favorable; not only were two previously known colonies blooming, but Dr. Wallace Kennedy, of Metter, had discovered near there a new one, which had escaped burning for a number of years and approached the normal arborescent habit of the species.

Pollen was accordingly carried, by what I can not refrain from terming an "automobee," from one locality, which may be designated A, some 5 miles to locality B, and from the latter 75 miles to locality C. The pollinated plants were carefully located by landmarks, and Dr. Harrold planned to return in the fall to see if any seed had matured. He was unfortunately prevented from doing so by serious illness, so what occurred at locality C is indeterminate. During the winter Dr. Kennedy went out to locality B, and found that capsules had actually formed on the pollinated plants, but by that time dehiscence had occurred, and the contents had fallen out, so the seed of the species is still unknown to science. Horticulturists have now become interested, however, and clumps from different colonies have been planted side by side on the grounds of Dr. Lee, in Macon, and of Professor De Loach, in Statesboro, where fire can be kept out and the plants watched closely, so by another year we should know what the seed is like, and have some from which seedlings can be grown for cultivation elsewhere.

Another group of plants on which data as to geographic range were being sought on this trip was the phloxes. Many of the counties of Georgia traversed yielded one which, though exceedingly variable in habit and leaf-shape, could only be classed as *P. glaberrima* L. In an alder thicket near La Grange, Troup County, we found a colony of the tallest plants of this species on record, attaining a height of 175 cm. Driving south through Webster County and watching the roadsides for plants of interest, we suddenly caught a flash of purple on a plant which looked different

FIG 2 ONE OF THE FEW *SARRACENIA* MEADOWS

STILL PRESERVED NEAR THEODORE, ALABAMA. THE SPECIES ARE *S drummondii* AND *S sledgei*, WITH INNUMERABLE HYBRIDS BETWEEN THEM, SHOWING ALL SORTS OF COMBINATIONS OF CHARACTERS.

from any previously seen On investigation this proved to be *Phlox floridana*, which had not been previously reported north of Thomas County, so that our find extended its known range by more than 100 miles Other new stations for this species in Georgia and Alabama were also found later

Showiest of all the species of *Sarracenia* is the white-top pitcher-plant, usually known technically as *S. drummondii*, although Rafinesque's name *S leucophylla* has many years' priority. Amateur botanists have reported it to grow as far up as North Carolina, but the northernmost locality represented by specimens in herbaria is Americus, Georgia. After an hour's search in that vicinity we found in a swamp a small colony which, by a fortunate chance, had not been destroyed by cultivation. Here the stock of the species for Mr. Burk's collection was obtained, and although it is still too early to tell whether the clump planted outdoors in southern New Jersey will survive, those wintered over in the cool greenhouse have grown and bloomed well (See Fig. 1)

Another member of the genus does not grow east of Mobile, Alabama, so we traveled slowly toward that place, collecting various plants of interest along the way The technical name of the species in question is *S sledgei* Macfarlane, and, as its flowers are lighter in color than those of any other species, it seems most aptly termed the pale pitcher-plant This proved to occur in a number of swamps, and we soon had some plants ready to send off Here we were so fortunate as to meet Mr. T. S. Van Aller, who not only inspected our plants and certified them as safe for shipment, but also guided us to several pitcher-plant meadows which we would not have found otherwise. In most of

the localities draining, burning and other destructive activities of civilized man have greatly reduced the numbers of these plants, but one locality near Theodore proved to be still undisturbed (See Fig. 2) Here countless thousands of *S sledgei* and *S drummondii* grew together, along with a host of hybrids showing every conceivable gradation between and combination of the characters of the two parents It seems a pity that there is no one in the region sufficiently interested in conservation to buy up this bit of meadow and save it for investigation by geneticists and enjoyment by nature lovers of the future

In April, 1910, while carrying on his fascinating studies of the relations between insects and pitcher-plants, Dr Frank Morton Jones had spent some time at Theodore, and had observed in one near-by meadow a pink-flowered form of *S venosa* He had furnished us approximate directions as to its location, and we soon found what appeared to be the right spot. In July, of course, pitcher-plant petals are withered, but we dug a few plants and shipped them to Philadelphia in the hope that they might bloom in the greenhouse the following spring This hope has now been realized; and it turned out that we had struck the right spot The parts of the flower which in most pitcher-plants are green or bronzy—the bracts, sepals and style-umbrella—are in this one nearly white, while the petals have a lovely rose color, unlike that of any other *Sarracenia*.

Few herbarium records existing for Mississippi plants, we visited bogs in two of the eastern counties of that state, obtaining specimens of several Sarracenias and phloxes. Next we went to Havana, Alabama, and found the famous colony of the hybrid spleenwort (*Asplenium ebenoides*)—the only one in which fertility has been attained—to be in good condition. We then called on Dr. Roland M. Harper at Tuscaloosa, and obtained from him directions as to certain *Sarracenia* localities in the northern part of this state. Along the Sipsey River we found a colony of the Allegheny filmy-fern (*Trichomanes boschianum*), but search for its diminutive relative, *T. petersii*, was unsuccessful

In Chilton County we located a colony of a red-flowered pitcher-plant, but it was not in good enough condition to establish its identity. We then set out for the valley of the Little River east of Fort Payne, where a yellow-flowered one was reported. In spite of many hours' search in every conceivable type of habitat, we were unsuccessful in finding it there, but Dr. Harper had fortunately observed it, also, near Center. On reaching that place we found that, although recent clearing of the land for agriculture and burning over of the swamps, even where no such use was practicable, had nearly exterminated it, a few small clumps had somehow managed to escape destruction Both in the field and in the greenhouse, where it bloomed the following spring, this plant showed a number of differences from its nearest relative, *S. flava*, and is to be classed as an independent species.

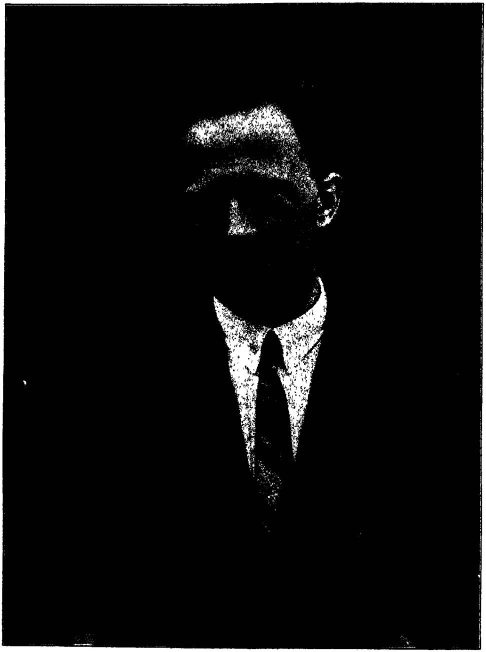
The mountains of North Carolina were our next objective, for there grows the red-flowered pitcher-plant known as *Sarracenia jonesii*, the distinctness of which had only been recognized in 1929. Its colonies proved to have been nearly destroyed by drainage of the swamps and by the raids of vandals from the towns, but enough remained to enable this species to be added to the collection. With it grew some beautifully veined *Sarracenia venosa*. Ordinarily, when two closely related species or varieties exist, the more southern one tends to grow in the coastal plain, the more northern in the mountains; in this case, however, the southern representative grows both at low and high elevations. We also found hybrids between *S. venosa* and *S. jonesii* as yet undescribed.

Never having had an opportunity to make habitat photographs of and color notes on the rather rare *Phlox amplifolia* Britton, we then made an effort to find this plant in several counties where it had been reported. The roadsides were gay with another member of the genus—*P. carolina* L., long mistaken for various other species—but for some time we were unable to find a single colony of the one especially sought Finally, however, it turned up in thickets in the vicinity of Willets, Jackson County, and the desired data upon it were obtained.

Leaving the mountains, we next drove to Charleston, South Carolina, where some of the specimens in the Elliott Herbarium, preserved at the Charleston Museum, were studied, and then made for Summerville How abundant pitcher-plants formerly were here is well shown by the splendid photograph in Macfarlane's Monograph on the family in Engler's "Pflanzenreich"; but when we reached the spot where this had been taken, a very different sight met our eyes Drainage of the swamps and burning of the woods had destroyed practically everything, and it was only after considerable search that we found even a single pitcher-plant in the midst of the rank, weedy grass and brush that had come in.

Three species of pitcher-plants remained to be collected at the northernmost margin of their range, so that they would be as hardy as possible. Eastern South Carolina proved, however, to be poor collecting ground, for droughts extending over a period of years had so lowered the water-table that many former swamps were now dry land Moreover, the local farmers had taken to planting crops in the lower areas, and many a time when we pushed through pine woods toward what should have been a *Sarracenia* bog we found only a *Zea Mays* or *Gossypium* bog instead *Sarracenia minor* was finally obtained in the neighborhood of Florence, South Carolina, and we then made for Lake Waccamaw, North Carolina. A few months before, Mr. Benedict had discovered here a northern outpost of the Florida swamp-fern, *Dryopteris floridana*, and of this we were able to obtain a good series of pressed specimens.

The sweet pitcher-plant, *S rubra*, eluded us for some time, but we finally located it in wet woods on the outskirts of Fayetteville, and roots were duly collected Before leaving this part of the country, an attempt was made to obtain some of the remarkable little insectivorous plant, *Dionaea muscipula*, from a northern marginal occurrence, but the drought proved to have destroyed practically all of it, and only a very small clump could be obtained for planting out in the New Jersey preserve. Here it has survived the first winter, however, so there is some hope that it may become established there. The last pitcher-plant, *S flava*, was obtained near New Bohemia, Prince Charles County, Virginia, and the series was complete



DR WERNER HEISENBERG

THE PROGRESS OF SCIENCE

AWARD OF THE NOBEL PRIZES IN PHYSICS TO PROFESSORS HEISENBERG, SCHROEDINGER AND DIRAC

THE 1932 and 1933 Nobel prizes have been granted to three leaders in theoretical physics. Werner Heisenberg, of Leipzig, was awarded the 1932 prize for his development of quantum mechanics leading to the discovery of the allotropic forms of hydrogen; the 1933 prize is divided between Erwin Schroedinger, of Berlin, now at Oxford, and P. A. M. Dirac, of Cambridge, England, for the new form they have given to the quantum theory of the atom. By this award the high estimation and the great importance of purely theoretical work for the development of modern physics is emphasized by the Nobel Committee, which is known usually to lay special stress rather upon the experimental side.

Since the beginning of this century atomic physics has won more and more importance. The nuclear model developed just before the war by Rutherford and Bohr created a very suggestive picture of the atom leading to innumerable experimental discoveries, especially in spectroscopy and the study of the reactions between atoms and electrons. The idea of the heavy, positively charged nucleus, surrounded by negatively charged light electrons rotating like the planets around the sun, appealed to the imagination of scientists, and attracted the interest and collaboration of most physicists. But after the very intensive work of about ten years it became more and more obvious—as was early predicted by Niels Bohr—that this theory was only a preliminary step in the study of the atom and that the laws of classical mechanics had to be changed when dealing with the minute dimensions of the atom, a world ruled by Planck's constant h of elementary action. This change came from three different sides nearly simultaneously, and these three different modes of the new mechanics have now been crowned by the highest scientific honor.

Indeed, the new mechanics gives an entirely consistent theory of all atomic and molecular phenomena outside the nucleus, as long as the velocities involved are not comparable with the velocity of light; and its results have with this restriction so far never been found to be in contradiction with the experiments. The field thus covered includes all of spectroscopy, the collision phenomena between molecules and electrons and the mystery of chemical forces. There are even attempts to understand processes of radioactivity taking place inside the nucleus. The consequent expansion of the theory led after many struggles rather to a statistical than to a causal conception of nature. It modified thus our previous convictions concerning nature and almost crossed the borders of pure science reaching into the field of metaphysics.

Professor Heisenberg, who is now 32 years old, studied with Arnold Sommerfeld in Munich, with Max Born in Goettingen and with Niels Bohr in Copenhagen. He won his first reputation at the age of 21, when he introduced half quantum numbers for treating the natural multiplicity of spectral lines and their Zeeman effect, *i.e.*, their splitting in a magnetic field into groups of polarized lines. The idea of half quantum numbers was so original and new that it

DR. ERWIN SCHROEDINGER

created a real sensation when its youthful author defended it in a modest but very convincing way at a scientific congress in Goettingen against a whole group of colleagues, headed by Niels Bohr It is worth mentioning that these half quantum numbers reappear in his quantum mechanics

The idea of Heisenberg's mechanics was born in Copenhagen in the stimulating circle around his beloved teacher Bohr, but it was published and worked out in Goettingen in collaboration with Max Born and Pascual Jordan. Heisenberg's aim was to discard the unobservable "orbits" of electrons, which played a predominant rôle in the previous theory, and to deal only with properties like frequency and intensity of spectral lines which can be observed This method was recognized by Born as being in close connection with the well-known matrix symbolism of mathematics It was worked out by Born, Heisenberg and Jordan within a few months to a consistent theory of spectroscopy, including an attempt to quantize the electromagnetic field

One of the great successes of the new mechanics was Heisenberg's treatment of the problem of two and more electrons and his discovery of the "resonance coupling" between identical electrons. This discovery gives an explanation for the splitting of the helium spectrum into two—the para- and the ortho-helium spectrum The application of this result to the hydrogen molecule, where the two identical nuclei play the rôle of the two electrons of the helium atom, led D M. Dennison in Ann Arbor to the prediction of two allotropic forms of hydrogen, the para- and the ortho-hydrogen. His surprising prediction was later experimentally verified by K F. Bonhoeffer and P. Harteck in the "Kaiser Wilhelm Institut für physikalische Chemie und Electrochemie" in Berlin-Dahlem, and by Eucken and Hiller in Breslau

From a more general point of view, Heisenberg's greatest achievement was the recognition of the impossibility of the simultaneous accurate determination of the speed and the position of an electron, generalized in the famous uncertainty principle He was led to this discovery by the realization of the statistical meaning of the fundamental quantities of the new mechanics

Shortly after Heisenberg, but without connection with his theory, Schroedinger started from the conception of de Broglie, that the motion of particles may be represented by progressive waves By generalizing this idea he arrived at a differential equation for the wave motion which corresponds to the motion of particles in space in a manner analogous to that in which the change of the electromagnetic field described by Maxwell's differential equations corresponds to the motion of light quanta The conception of waves representing particles was very much strengthened by the fundamental discovery of Davisson and Germer, who showed experimentally that moving electrons can produce interference patterns, very similar to those of light waves

Schroedinger's differential equation gives the clue for the understanding of the quantized states of atoms and molecules which, up to that time, defied the treatment by continuous functions. In virtue of the possibility of applying well-known mathematical methods to his equation, Schroedinger opened a broad road to the solution of atomic problems, and in a series of brilliant papers he traveled a long way along this road. Many questions indeed, such as the problem of resonance coupling and of the hydrogen molecule, scarcely could have

DR. PAUL ADRIEN MAURICE DIRAC

been solved without his powerful equation

The explanation of the sharp energy states of atoms given by Schroedinger's wave mechanics is just as simple and "anschaulich" as the explanation of the well-defined tunes of a bell, given by the differential equations of classical mechanics In Heisenberg's quantum mechanics the discrete energy states were much more explicity postulated And yet, the physical contents of both theories have been shown by Schroedinger to be identical--in spite of their totally different aspects

The third scientist awarded the Nobel prize is P. A. M. Dirac After the stimulation received from the work of Heisenberg, he built up almost the whole system of quantum mechanics, independently of all other investigators, using his own mathematical calculus, the "q-numbers" The step-by-step development of this theory may still be considered as his greatest achievement Not only the consistency in every one of his works has to be admired, but still more their organic entity. The culmination of this series of articles is his famous light-theory, which for the first time connects the radiation process itself intrinsically with the mechanics of the atom His papers contain—apart from some more or less special applications--almost all the results of the non-relativistic quantum theories which are nowadays the common property of theoretical physicists.

The mathematical tool, the q-number algebra, developed by Dirac in these works, makes the reading of his papers more difficult; and his methods have often been the target of attacks because of lack of mathematical rigor. Nothing manifests more strongly the fertility of his ideas than the fact that it hardly is possible nowadays to find a theoretical physicist unfamiliar with q-numbers, nor any critic of the rigor of his δ-function method who would not use it himself—even though exhibiting his results with the more accepted methods to the public

The problems of relativistic quantum mechanics reveal another side of Dirac's abilities. The stepwise penetration of the subject does not seem to be possible here any more, and his mind is forced to greater jumps. We owe him one of the greatest successes of quantum mechanics — his theory of the spinning electron He showed in an ingenious way that the relativistic treatment of the electron reveals its magnetic property automatically, whereas Goudsmit and Uhlenbeck's idea of the spinning and magnetic electron had to be added from the outside to the edifice of non-relativistic quantum and wave mechanics His further development of this theory led him to such a fantastic conception of the nature of electrons that he himself may have doubted it; and yet it obtained a wonderful verification by Anderson's discovery of the positron, the real counterpart of the negative electron.

How similar is the goal which the three men attained, but how different is the way they work! We see Heisenberg, on the one hand, always in close contact with collaborators, transferring to them his sweeping enthusiasm; on the other hand, Dirac quite alone with his thoughts and his critical logic. Schroedinger shows an attitude intermediate between the two, working mostly alone, but brought closer to his colleagues by his artistic spirit.

Rudolf Ladenburg
Eugene Wigner
Princeton University

MEMORIAL HALL TOWER FROM THE HARVARD COLLEGE YARD

THE REGISTRATION HEADQUARTERS AND THE SCIENTIFIC EXHIBITS WILL BE HELD I MEMORIAL HALL

THE BOSTON MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

MEMORIES of the early years of the association's history come flooding in upon us as we prepare for this winter's Boston meeting For it was in Boston nearly one hundred years ago that the idea of the association in its present form was first proposed

Dr John Collins Warren, one of Boston's outstanding citizens and one of the most eminent American scientific men of his generation, had attended the seventh meeting of the British Association for the Advancement of Science held at Liverpool in September, 1837. So impressed was he with the advantages of a meeting of this kind that upon his return to Boston in August, 1838, he at once undertook to form a similar association in America.

Cooperating with him toward this end were Governor Edward Everett (later president of Harvard and Secretary of State), former Lieutenant Governor Thomas Lindall Winthrop, president of the Massachusetts Agricultural Society and of the American Antiquarian Society, and Mr. Justice Joseph Story, Dane professor of law at Harvard and a justice of the Supreme Court of the United States.

A Committee of Correspondence of the American Association was formed, and on October 30, 1839, Dr Warren wrote a circular on the subject of the British Association and sent it to the printer, ordering fifty copies

The American Philosophical Society in Philadelphia, as the oldest scientific society in America, was requested to take the initiative in the formation of an American Association for the Promotion of Science To this society Dr Warren wrote a letter, enclosing "a circular from a meeting of gentlemen at Boston."

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—Bachrach

DR. C. J. DAVISSON
BELL TELEPHONE LABORATORIES; CHAIRMAN OF THE SECTION OF PHYSICS.

DR ARTHUR B. LAMB

PROFESSOR OF CHEMISTRY, HARVARD UNIVERSITY; CHAIRMAN OF THE SECTION OF CHEMISTRY.

DR. R. T CHAMBERLIN

PROFESSOR OF GEOLOGY, UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION OF GEOLOGY.

DR. V. M. SLIPHER

DIRECTOR OF THE LOWELL OBSERVATORY; CHAIRMAN OF THE SECTION OF ASTRONOMY.

DR. A. S. PEARSE

PROFESSOR OF ZOOLOGY, DUKE UNIVERSITY; CHAIRMAN OF THE SECTION OF ZOOLOGICAL SCIENCES.

But the society, after careful consideration of the matter, came to the conclusion that it was inexpedient to undertake the organization of such an association at that time And so this attempt came to nothing.

Simultaneously with Dr Warren's efforts to form an American Association for the Promotion (or Advancement—he used both words) of Science along the lines of the British Association, the Reverend Dr. Edward Hitchcock, state geologist of Massachusetts, was endeavoring to form a general association of geologists and others for the purpose of broadening the horizon of the scientific men throughout the country through the medium of friendly intercourse and discussion Indeed, Dr. Hitchcock had begun his efforts toward this end at least a year before Dr Warren had returned from England.

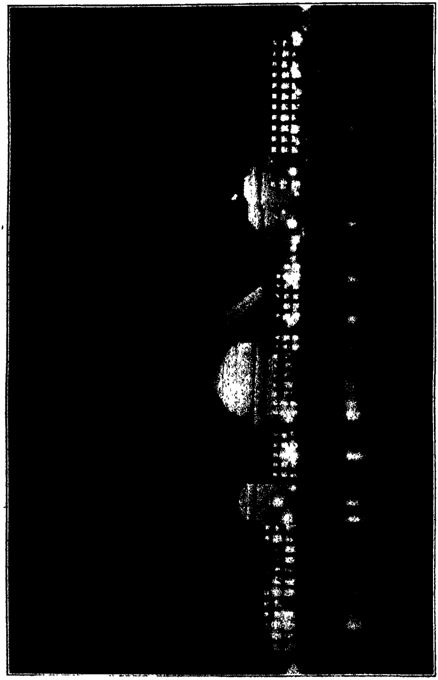
DR. K. M. WIEGAND
PROFESSOR OF BOTANY, CORNELL UNIVERSITY; CHAIRMAN OF THE SECTION OF BOTANICAL SCIENCES.

Now at that time interest in the investigation of the country's natural resources of all sorts was very great No less than eighteen states had organized more or less elaborate and comprehensive geological surveys, of which the first three were those of North Carolina (1823), South Carolina (1824) and Massachusetts (1830), and the advantages to be gained by correlating the work of these several surveys were evident to all.

Largely as a result of Professor Hitchcock's initiative, the Association of American Geologists was organized in 1840 in Philadelphia. At the third meeting held in Boston in 1842 the name was changed to the Association of American Geologists and Naturalists. At the last meeting, which took place in Boston in 1847, the organization agreed to resolve itself into the American Association for the Promotion of Science, which at its first meeting, held in Philadelphia in 1848, changed its name to the American Association for the Advancement of Science.

DR. WINGATE TODD
PROFESSOR OF ANATOMY, WESTERN RESERVE UNIVERSITY SCHOOL OF MEDICINE; CHAIRMAN OF THE SECTION OF ANTHROPOLOGY.

In 1874 this association was incorporated under the laws of the State of Massachusetts, the articles of incorpora-



—M I T. Photo Service

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AS SEEN FROM THE CHARLES RIVER AT NIGHT

tion passing the House of Representatives on March 10 and the Senate on March 17, and being signed by Governor W. B Washburn on March 19

Massachusetts from its earliest days has always fostered literature, science and the arts. In the constitution of the state adopted on June 16, 1780, we find ". . . it shall be the duty of Legislatures and Magistrates, in all future periods of this Commonwealth, to cherish the interests of literature and the sciences, and all seminaries of them . . . to encourage private societies and public institutions, rewards and immunities, for the promotion of agriculture, arts, sciences, commerce, trades, manufactures, and a natural history of the country . ." Under this new constitution the American Academy of Arts and Sciences was incorporated in 1780

Going still further back, to the time of the early settlement of New England, we find some very interesting facts.

—Bachrach

DR. WESLEY C. MITCHELL
PROFESSOR OF ECONOMICS, COLUMBIA UNIVERSITY; CHAIRMAN FOR THE SOCIAL AND ECONOMIC SCIENCES.

DR. W. R. MILES
PROFESSOR OF PSYCHOLOGY, YALE UNIVERSITY; CHAIRMAN OF THE SECTION OF PSYCHOLOGY.

Shortly after the first settlers had come to Massachusetts, about 1645, there existed in England an organization referred to in letters written at that time as the Invisible College. This Invisible College consisted of weekly meetings of a number of prominent men, including John Winthrop, for the purpose of discussing experimental science, a proceeding then regarded as wholly unorthodox.

In the troubled times that followed these men planned to emigrate to New England, there to establish a Society for Promoting Natural Knowledge. But immediately after the Restoration King Charles II took this organization under his protection, and it became the Royal Society.

Dr. Cromwell Mortimer wrote in 1741 that, as the proposed emigration of learned men from England to New England to form a Society for Promoting Natural Knowledge did not take place, Mr. John Winthrop first founded the

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PERMANENT SECRETARY OF THE AMERICAN COUNCIL OF LEARNED SOCIETIES; CHAIRMAN FOR THE HISTORICAL AND PHILOLOGICAL SCIENCES

College at Cambridge, in New England, since known by the name of Harvard College.

So much for the past Bearing this in mind, let us look forward to the immediate future

The coming meeting at Boston is the ninety-third meeting of the association. It is regarded as the fifth Boston meeting, although it will really be the sixth meeting in the Boston-Cambridge area. The association's second meeting was held in Cambridge in 1849, and the

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twenty-ninth (1880), forty-seventh (1898), sixty-first (1909–1910) and seventy-sixth (1922) meetings were held in Boston. In addition to these, the eighteenth meeting was held in Salem in 1869.

For the 1933 meeting the official headquarters will be at the Hotel Statler, in Boston, where the first general session, as well as a number of special events of importance, will be held. A large num-

—*Cornell—Dayton, Ohio*

DR. CHARLES FRANKLIN KETTERING
PRESIDENT OF THE GENERAL MOTORS RESEARCH CORPORATION; CHAIRMAN OF THE SECTION OF ENGINEERING.

ber of sections and affiliated societies will meet at this time

The institutions welcoming the associations are Harvard University, Massachusetts Institute of Technology, Simmons College, Boston University, Boston College, Northeastern University, Tufts College, Wellesley College and Weston College Thus the colleges and universities in the whole metropolitan area will participate as hosts to the visiting members, although for general convenience the section sessions will be held in Cambridge, in the lecture rooms at Harvard University and at the Massachusetts Institute of Technology.

The main registration headquarters will be at Memorial Hall, Harvard University, where registration facilities will be in operation from Tuesday noon, December 26, and will be maintained throughout the week A subsidiary registration desk will be maintained in the main lobby of the central building of the Massachusetts Institute of Technology especially for the benefit of members of the engineering and other sections of which the meetings will be held at the institute

—Bachrach

DR WALTER F DEARBORN

PROFESSOR OF EDUCATION, HARVARD UNIVERSITY, CHAIRMAN OF THE SECTION OF EDUCATION.

DR. A. R. MANN

PROVOST OF CORNELL UNIVERSITY; CHAIRMAN FOR AGRICULTURE.

Extensive commercial, college and secondary school exhibits will be displayed at Memorial Hall, Harvard University, in close proximity to the main meeting places of the various sections.

The first general session will be held at the Hotel Statler on the evening of Wednesday, December 27. After the addresses of welcome, the retiring president, Dr John J. Abel, of the Johns Hopkins University, will speak on "Poisons and Diseases, and some Experiments with the Toxin of *Bacillus tetani.*" Dr. Abel's address will be followed by a general reception.

In the afternoon of Thursday, December 28, Professor William Morris Davis will deliver the Hector Maiben lecture, speaking on "The Faith of Reverend Science." On the evening of the same

day Dr Henry E. Sigerist, of the Johns Hopkins University, will give the Sigma Xi lecture, his title being "The Foundation of Human Anatomy in the Renaissance."

The Honorable Henry A. Wallace, Secretary of Agriculture, will give an address on "What Can Engineering Do for Agriculture?" in the evening of Friday, December 29, in the ball room of the Hotel Statler.

The Sedgwick Memorial Lecture, given under the auspices of the Biological Department of the Massachusetts Institute of Technology, will be at Huntington Hall, 491 Boylston Street, Boston, on Saturday, December 30, in the afternoon. Dr. Henry Fairfield Osborn, honorary president of the board of trustees of the American Museum of Natural History, New York, will speak on "Aristogenesis, the Creative Factor in Evolution"

The local committee is arranging a number of social events especially for the entertainment of visiting ladies, including visits to Wellesley and Radcliffe Colleges, various museums, etc.

The Boston area is too well known to require extended description. Historically, educationally and by virtue of its geographic position, it is familiar to many, if not to most, American scientists. Itself of great historic interest, its proximity to Plymouth, Salem, Lexington and Concord, as well as to other places interwoven with early colonial life and aspirations, make it a center of unusual significance to all Americans.

While Boston as a political and administrative unit is a city of approximately only 800,000 people, the thirty cities and towns of the metropolitan area, all within a radius of fifteen miles, make the real or "greater" Boston the fourth city of the United States in population, with about 2,250,000 people. The commercial significance of Boston, based upon the essential industries of wool, cotton, boots and shoes, machinery, etc., is well known.

Its beautiful park system, excellent harbor, ease of access to mountains, diversified seashores and charming rural districts need only be mentioned. To those who will attend the Boston meeting this year under winter conditions, its significance as an educational and scientific center will perhaps be the chief item of importance, for Boston is the greatest educational center of the western world, including within its limits, or within a radius of fifty miles, not only the institutions which will act as hosts on this occasion, but numerous other colleges, schools of music and art, preparatory and vocational schools. The personnel and student bodies of these institutions would in themselves make up a city of many tens of thousands.

Among the places of interest in Boston and Cambridge may be mentioned the Peabody Museum, the Germanic Museum, the Museum of Comparative Zoology, the Fogg Art Museum, the Astronomical Observatory and the Botanic Gardens, at Harvard; the Nautical Museum of the Massachusetts Institute of Technology; the Boston Art Museum, Gardner Museum, Boston Public Library, Boston Society of Natural History, State House (historical collections), Old State House, Watertown Arsenal, Charlestown Navy Yard, Bunker Hill, Old South Church, Paul Revere House, etc. An illustrated booklet descriptive of Boston and its environs will be supplied to each registrant at the meeting through the courtesy of the Boston Chamber of Commerce.

Respect for the past and for the achievements of our predecessors is a necessary basis for a sound and well-reasoned approach to the problems of the present and the future. But respect for the past does not imply stagnation. No better illustration of this fact can anywhere be found than in the development of the scientific, cultural and educational organizations and institutions in and about Boston.

AUSTIN H. and LEILA F. CLARK

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THE SIGNIFICANCE OF THE EMOTIONAL LEVEL

By Dr. WALTER B. CANNON

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AN emotion, as the word implies, is a condition that moves us. Indeed, when we have an experience pervaded by a powerful emotional element we speak of it as a *moving* experience. The force which is exhibited when a strong emotion seizes upon us may be so dominant as to sweep away all considerations of prudence. The mystery of this force has long roused the interest of philosophers and biologists. Spinoza and Descartes have discussed its nature, and Darwin and others have studied its manifestations. Modern researches have added considerably to our knowledge of its sources and its effects. I propose that we consider together some recent evidence as to the physiological nature of emotional excitement.

In order that we may be quite specific in our examination of the evidence, I suggest that we select at first a single emotion—that of rage—and study its characteristics. In a physiological sense an exhibition of rage follows what may be called a "reaction pattern." When we see a man who is enraged we note his crouching body, his frowning brow and his lips drawn close over clenched teeth as he growls his threats. His fists are tightened or are grasping a seized weapon. These, however, are the superficial aspects of the pattern. An examination of the deeper changes would reveal an acceleration of the heart beat, a rise of blood pressure, an increase of blood sugar, a redistribution of blood in the body, a greater output of adrenal secretion and a digestive process that is inhibited. Some of these changes can be directly observed in man; and others are inferred from their relations in lower animals.

It is typical of these features of the pattern response of rage that they have many of the characteristics of reflexes. First of all, we *do not learn* to be enraged; like laughing and weeping, the rage reaction is seen soon after birth as a mode of behavior fully prepared for display. Again, like a reflex, it has a *definite stimulus;* just as tickling will evoke laughter, so anything that hampers or checks or thwarts the satisfaction of any strong impulse in us will call forth the rage response. Like a reflex, also, the reaction of rage is *prompt* when the stimulus is appropriate. And it is *permanent;* the typical pattern will be evoked at different ages in the same individual when the appropriate conditions are present. Furthermore, it has a *constant* and fairly *uniform* manifestation in different races; one may not understand the language in a foreign country, but on sight one can readily understand the attitude of an enraged native. Again, it is characteristic of reflexes that they are *useful*—sneezing and coughing, for example, reflexly clear the

respiratory passages of irritating material. Similarly, the changes which occur in rage, especially the deep changes I have referred to above, can be reasonably interpreted as adaptations of the organs of the body such as to render the individual more effective in the struggle which is likely to accompany the aggressive attitude that is associated with rage. Thus, the faster heart rate and the higher blood pressure hasten the transport of the larger quantity of oxygen needed for increased activity and the larger quantity of carbon dioxide resulting from the oxidized metabolites; and the increase of blood sugar provides fuel for laboring muscles. The other changes, likewise, fit into this picture. Finally, it is a fact of primary importance that the *expressions* of emotions in man and lower animals, as Darwin pointed out in his classical volume, are *similar*. When the hungry dog is enraged, by thwarting, for example, his instinctive act of eating, he, like the angry man, shows his teeth and growls and manifests the deep visceral changes already mentioned. Such, then, are some of the characteristics of the reaction of rage

When we compare the nervous system of man and lower animals the most striking difference is to be found in the relatively enormous development of the cerebral hemispheres, with their much folded cortical layers, in man as compared with any other vertebrate form. These great masses of nervous tissue, developed from the anterior portion of the brain stem, are new and special features in the human being, sharply differentiating him from all other related fellow-creatures. The spinal cord and the brain stem, on the other hand, are much less altered Indeed, they can be regarded in their general aspects as practically common to man and to other higher vertebrates.

That the reactions of the two parts of the nervous system which I have just mentioned are strikingly different from one another is well known. The responses of the spinal cord and the brain stem, when a stimulus is applied, are routinely prompt, uniform and stereotyped. The patellar and pupillary reflexes are examples. Indeed, it is in these lower parts of the nervous system that reflexes, simple and complex, have their central stations The reactions which involve the cortex of the cerebral hemispheres, on the other hand, instead of being prompt are delayed—there may be an indefinitely long interval between the reception of the stimulus and any behavior precisely related to it. Also, instead of being uniform, these cortical reactions are unpredictable; the same situation presented to different individuals may call forth extraordinarily different activities. And finally, instead of being stereotyped, these reactions are rather easily modifiable; in fact, the whole process of education is directed toward modifying the attitudes and activities of individuals on the basis of previous social experience. We see, then, that there is a sharp separation between the fixity and monotony of the responses from the spinal cord and the ancient portion of the brain, and the uncertainty and variety of the responses from the much more complex cerebral hemispheres.

The question now arises as to where the neurone patterns lie which express emotional excitement. Are they stationed in the primitive portion of the nervous system or in that portion which has been so highly developed in the human being? Evidence in answer to this question was obtained some years ago by Britton and myself in experiments on the cat, in which, immediately after etherization, we rapidly destroyed the cerebral cortex (which subserves consciousness), and then permitted the remnant of the animal to emerge from the anesthetic. Almost as soon as freed from anesthesia the preparation exhibited an extraordinary group of phenom-

ena which we called "sham rage." The hairs stood on end so that the tail was like a bottle brush. The pupils were widely dilated, sweat poured out on the toe pads, the blood pressure rose to 200 mm of mercury or higher, the heart rate went up from a normal of approximately 120 beats per minute to 250 or even 300 beats, and the blood sugar mounted until at the end of two hours it might be five times the usual concentration. Here you will note a manifestation of the deeper changes occurring in the rage pattern, but, I would emphasize, in the absence of any possible functioning of the cerebral cortex. Later my colleague, Bard, studied this preparation still further and learned that it was possible to remove both cerebral cortices, the corpus striatum and, indeed, all the brain anterior to the lower posterior portion of the diencephalon without disappearance of the sham-rage phenomena. When he removed this small portion, however—a bit of tissue in the cat hardly larger than the tip of the little finger—the phenomena entirely vanished and were replaced by decerebrate rigidity. It appeared clear that the neural mechanism for the display of the pattern of rage is located, in the cat, in the hypothalamus. For present purposes, it is sufficiently accurate to speak of this region as the thalamic region. It is here that we find what we shall call the "emotional level."

This location of the neurone pattern which manages the bodily exhibition of the rage response has important significance in explaining many of the phenomena not only of rage but of other emotions as well, and also certain conditions which are not emotional in character. Let us survey together these variously important bearings of the emotional level on other parts of the organism, and in relation to facts already considered.

In the first place, it is obvious that the presence of the neural arrangement for the reaction of rage in the thalamic region, where ocular and other reflexes have their seat, is consistent with the facts already stated which show that the bodily manifestations of rage have the typical features of simple reflexes. It has those characteristics because it is managed in that part of the brain in which the reflex type of activity is natural and inherent.

In the second place, the locus of the center for the rage response in the thalamic region explains why the expression of rage has many features that are common to man and to lower animals —why both snarl and show their teeth. The thalamic region is in the ancient brain stem which has undergone relatively little change in the course of vertebrate evolution, and therefore its structure and function have not been greatly altered in the development from lower mammals to human beings. Because the brain stem is similar in higher vertebrates the responses from it are similar.

A third significant fact is found in the appearance of the characteristic posture and features of rage after the cortex has been removed. Evidently, this fact proves that there is a double control of certain of the peripheral effectors from two levels—from the cortex and from the thalamic region. When the cortex is removed, voluntary control is abolished but control from the emotional level is still retained. We see illustrations of this in the primary stage of ether anesthesia or when nitrous oxide is used as an anesthetic. Under these conditions the individual may be regarded as chemically decorticated. Voluntary control is abolished, but the emotional level is still active. The patient under light ether may show signs of rage by fighting and muttering at the attendants who attempt to restrain his movements, and the patient under nitrous oxide may have expressions from the emotional level in laughter or tears, for the anesthetists say that

laughing gas might quite as reasonably be called weeping gas. Again, in cases of hemiplegia the patient may have destruction of the motor cortex or interruption of the subcortical motor pathway on one side with attendant abolition of voluntary control of facial muscles. Tell such a patient a funny story, however, or make him sad, and he will appropriately laugh or cry, with bilateral symmetry of the response on the two sides of the face. On the other hand, there may be damage of the structures on one side in the thalamic region; then the patient has symmetrical control of the facial muscles if they are voluntarily innervated, but an appeal to the emotional level results, for example, in a one-sided smiling or weeping. Most interesting of all, in relation to the studies on experimental animals, are those human cases of pseudo-bulbar palsy in which cortical control of the thalamic region is largely abolished. In such cases the emotional expression may be indefinitely prolonged. There are records of patients who have wept or laughed for hours without stopping. In one such instance laughter started at 10 o'clock in the morning and continued steadily till 2 o'clock in the afternoon! It may be noted that these signs of sadness or hilarity are without any reference to the actual situation

In connection with the evidence that the removal of cortical influence, either mechanically by operation, or chemically by anesthetics, or pathologically by disease, releases the emotional level and allows it to manifest its functions to a supreme degree, there is an interesting consideration regarding sleep It appears logical to suppose that sleep could not possibly be a simple subsidence or abolition of the functions of cerebral cortex. If that were the case we should expect sleep to be attended by a rather elaborate exhibition of emotional reactions. Instead, of course, it is a period of lessened activity throughout the organism. Since the diencephalon is a region in which many bodily activities have their seat and which in the absence of cortical government occasions an extraordinary exaggeration of these activities, the conclusion would seem to be rational that sleep might have its source in some change in the diencephalon. The interesting experiments of Hess, in Zurich, which show that stimulation of certain areas in this region causes animals promptly to become somnolent and lie down to rest and slumber, offer strong support for this suggestion.

In relation to the double control of lower motor neurones from the two levels—the cortical and the thalamic—previously noted, there is an important distinction to be made between the control of skeletal or facial muscles and the viscera. Whereas facial muscles, for example, are controlled from both regions, so that there may be both voluntary and emotional expression, the viscera are controlled only from the emotional level It should be obvious that although, in the presence of emotion-provoking circumstances, the cortex by voluntary act may set the features in a state of calm or indifference, the absence of ability of the cortex to affect directly the visceral portion of the thalamic pattern would not permit the palpitating heart, the high blood pressure or the active sweat glands to be inhibited. Thus a person may put on a bold face because cortical government of the facial muscles can at times dominate the emotional government of these muscles, but he may be boiling inside because the cortex can not govern the organs of the thorax and the abdomen.

Another consideration which has an importance, especially for psychology, is the evidence which points to the thalamic region as the origin of that special quality—the "affect" or "feeling tone" associated with sensation—which changes the "object-simply-perceived," as William James framed it, into the "object-

emotionally-felt." The testimony that the source of the peculiar experience of emotion is found in the diencephalon is derived chiefly from clinical observations on patients who present the so-called "thalamic syndrome." Such patients, as Henry Head has noted, may have abolition of cortical control of the thalamic region on one side. In these circumstances the phenomena which result can be best explained as an exaggerated activity of the thalamus on the side of the lesion. Associated with this greater activity is a very striking intensification of feeling tone or emotional experience, but only on the affected side. On that side, contact with a cold test-tube is felt as something extremely disagreeable On the other hand, contact with a warm test-tube yields exquisite delight. A pin-prick, felt as a slightly unpleasant sensation on the normal side, is reported, when tried on the other side, as being absurdly painful. And even if there is a central source of elation, as, for example, when martial music is played, the effect again is unilaterally exaggerated.

The points just detailed, taken in relation to previous evidence, have an important bearing on a well-known theory of emotion. You are doubtless aware of the suggestions made by William James and Carl Lange which resulted in the so-called "James-Lange theory" of the origin of emotional experiences. In general statement they attributed the emotional elements in consciousness to reverberations from peripheral changes, especially those arising from modified function of the viscera. Does not the recently emphasized rôle of the emotional level offer an alternative explanation? We have seen clear evidence that the thalamic region when excited discharges downwards to skeletal muscle and the viscera, and, as Head's cases prove, it simultaneously discharges upwards to the cortex. If we did not know the rôle of the thalamus as a source of impulses discharged in the two directions, we should naturally suggest, as James and Lange did, that the visceral disturbances are the source of emotional feelings. It is obvious, however, that the James-Lange theory can not account for the striking unilateral intensification of affective tone in the cases of unilateral damage to the cortico-thalamic tract, described by Head. Furthermore, the theory fails to account for the continuance of emotional experience in persons with transection of the cervical cord whose viscera are no longer able to report to the cortex.

Still another interesting point related to the emotional level in the diencephalon is the explanation it offers of the mysterious character of emotional experience. We probably have no conscious states associated directly with the nervous processes occurring in the thalamic territory Certainly it is true that reflexes in that region, such as those governing the iris and those concerned with body posture, are not attended by consciousness. If we may assume that the pattern reactions of neurones which operate in this region are not immediately associated with conscious states but influence consciousness only when they discharge to the cortex, there would be a reasonable explanation of the mystery. The emotional element would be something added to the perceived object, but added suddenly and intensely from outside the conscious realm. Thus might be explained certain expressions in common use. Persons testify to being "surprised" by an emotional experience, to being "seized" by powerful feelings, to being "possessed." They testify that something "surged up within them" and controlled their actions. All these sayings, which are taken from daily experience, are readily accounted for if we regard the emotional level as being subconscious.

In order to make clear the next matter of significance in the emotional level

—the way in which emotions may profoundly influence the organism—I must first present some basic considerations concerned with our two environments. We are all aware of our external environment, the structure and motions of objects that surround us, which we learn about through our sense organs. By means of these sensitive areas on or near the body surface there are sifted into us impressions of air vibration, contact, chemical change and rays of light which start impulses which are transmitted along nerve paths to the cerebral cortex and there are combined in perceptions of sound, touch, smell or taste, and vision. From the cortex nerve impulses pass down to skeletal muscles. By means of them, we directly or indirectly produce all the varied alterations of our surroundings, such as are seen, for example, in airplanes, ocean liners, radio transmission and the other miracles of present-day civilization. Commonly we regard ourselves as living in this external environment. In fact, however, we are shut off from it by a layer of dead material—the horny covering of the skin or the mucous covering of other parts of the body surface. All that is really alive within us is bathed in a fluid—the rapidly moving blood and the more slowly moving lymph. It is in this "fluid matrix" of the organism that the living parts reside. This constitutes what Claude Bernard called the "internal environment."

Variety may be the spice of life so far as the external environment is concerned, but constancy is of primary importance for the internal environment Indeed, only by the maintenance of a fair degree of constancy in some of the important constituents of the fluid matrix are we permitted to continue our ordinary existence. For example, the usual concentration of blood sugar is approximately 100 mgm in 100 cc of blood, or 100 mgm per cent.—a heaping teaspoonful for an adult. If the concentration falls to about 45 or 50 mgm per cent., convulsions are likely to arise and a continued fall to a lower level will result in coma and death. Or take calcium as another constituent. If the calcium concentration, which is normally about 10 mgm per cent., is reduced to half that figure convulsions occur, and if it rises to 20 mgm per cent. the blood may become so viscous that only with difficulty may it be made to circulate. Or consider the reaction of the blood. Ordinarily it is slightly alkaline. If it is changed until it becomes even in the least degree acid the individual will go into a coma, and if it is made slightly more alkaline than the normal degree he will go into convulsions. These examples illustrate the somewhat narrow margin of safety which prevails in the fluid matrix; that we are ordinarily free from the dangers of coma or convulsions indicates that there must be nice arrangements for the avoidance of the shifts that would bring upon us the menace of these dangers.

The mechanisms for constancy of the internal environment are to be found in the autonomic or involuntary nervous system. As you are well aware, there are three divisions of this system—the cranial and sacral or parasympathetic divisions, and the sympathetic. It is characteristic of the cranial division that it serves for the conservation of the bodily energies and the laying by of bodily reserves. Thus the vagus, as a part of this division, holds the heart in check when bodily activity is minimal. And the vagus also establishes a tonic state of the gastro-intestinal tract, and in cooperation with other representative nerves of the cranial division stimulates secretion of the digestive glands, when such function is appropriate, so that the food which is taken in is properly digested and utilized or stored for future use.

The sympathetic division consists of a series of ganglia arranged along either

side of the mid-line from the superior cervical ganglion high in the neck to ganglia low in the pelvis that are connected by so-called preganglionic fibers with the thoracic and upper lumbar portions of the spinal cord and that send out postganglionic fibers to smooth muscles and glands in all parts of the body. Smooth muscle thus innervated is found at the roots of hairs, in the walls of blood vessels, in the gastro-intestinal tract and in other viscera. The glands include not only those producing sweat on the skin surface, but also the digestive glands secreting into the alimentary canal.

It is characteristic of the sympathetic division that, when strongly excited, it acts as a whole. This unitary action of the sympathetic is reinforced by a chemical agent, adrenin, which nerves in this division cause to be discharged from the adrenal medulla and which, carried in the blood stream, has practically everywhere in the body the same effects as sympathetic impulses themselves. In this unitary action the sympathetic induces a faster heart beat, a contraction of blood vessels in the splanchnic area and in the skin with consequent rise of blood pressure, a dilation of the blood vessels in skeletal muscles, a contraction of the spleen where red corpuscles are concentrated, an enlargement of the bronchioles, an increase of blood sugar by discharge from stores in the liver, and a faster metabolism. It is a matter of considerable interest that these alterations are serviceable for maintaining constancy of the internal environment in a variety of circumstances which might disturb that constancy.

We can understand most clearly the functions of the sympathetic division if we examine the deficiencies of animals which have been completely deprived of their sympathetic system. By applying surgical methods it is possible to remove both ganglionic chains from such animals as the dog, the cat and the monkey. These animals will live for many months—indeed, some of our cats have lived for years—in the confines of the laboratory without at first sight appearing to be different from quite normal animals. The reason for this deceptive appearance of normality, however, is due to the circumstance that ordinarily the animals are not subjected to any disturbing stress. As soon as such stress is placed upon them they immediately manifest their deficiencies. For example, if they are emotionally excited there is no increase of blood sugar. The facilities for mobilizing this source of energy for muscular work have been destroyed. Again, if they struggle the heart may beat somewhat more rapidly because of lessening of the vagal check, but it can not accelerate as it normally does, because the accelerators in the sympathetic division have been removed. Furthermore, the blood pressure, instead of rising, actually falls in the absence of the sympathetic vasoconstrictor nerves. Also, whereas in the normal animal contraction of the spleen discharges concentrated corpuscles into the circulation and thus increases the carriers of the respiratory gases, this function in the sympathectomized animal is totally abolished. Moreover, the protection against temperature change is much impaired. In the normal animal, such as the cat, there occurs on exposure to cold an erection of hairs which enmeshes a thicker layer of air about the body—a layer which is a poor conductor of heat and which, therefore, protects against heat loss. Besides this change, there is, as in man, a contraction of the surface vessels so that the warm blood of the body is less generously delivered to the skin where it would lose heat to the cool outer atmosphere. In addition, there is a discharge of adrenin which, as mentioned above, accelerates the metabolism of the body and thus produces an extra amount of heat, which helps to prevent the lowering of body temperature. Note that all these changes—the erection of

hairs, constriction of blood vessels and discharge of adrenin—are brought about by the sympathetic system. But this system is not only active when the temperature tends to fall; it is serviceable, likewise, when the temperature tends to rise, for under such conditions it acts to increase the pouring-out of sweat which, on evaporating, cools the skin, and at the same time it relaxes the blood vessels and allows a larger amount of the warm blood from the interior of the body to flow through the cooled surface

The internal environment may be disturbed by both internal and external conditions. A few examples will make clear the nature of these disturbances. In muscular work, for instance, there is a great production of non-volatile lactic acid. The immediate way in which this can be got rid of effectively is by burning it to carbonic acid This requires the delivery of abundant oxygen to the muscles where the burning occurs, and at the same time the carriage of the resulting carbonic acid from the muscles to the lungs where it is breathed away This more ample transportation of the respiratory gases, which protects the body against the development of a dangerous acid reaction, is brought about by the sympathetic system, for the faster heart rate, the higher blood pressure from vasoconstriction—resulting in a faster blood flow to the active muscles where vessels are dilated—and the increased concentration of red corpuscles from contraction of the spleen are all due to action of the sympathetic. But muscular work also produces a large quantity of heat. If this could not be got rid of, our activities would be promptly checked by a degree of temperature so high that it would be perilous. The sympathetic is again effective, and by an abundant output of sweat prevents the body from becoming overheated. In muscular work, also, sugar is largely employed. There is little danger of the convulsions from low sugar content, however, because from the liver the sympathetic system releases sugar as it is needed. From these observations it is easy to understand why sympathectomized animals—the dog, for example, trained to run in a treadmill—become much less efficient if the sympathetic system has been removed.

I have considered the rôle of the sympathetic in maintaining constancy of the internal environment when there is danger that the temperature may fall. It is a point of great interest that sympathectomized animals when exposed to cold are no longer able to protect themselves by the usual reactions and have to utilize to an unusual degree the only defense which remains to them, namely, the automatic muscular contraction of shivering, which, by producing heat, helps to prevent the temperature from falling too low.

Now that I have laid this rather broad basis for an understanding of the influence of the sympathetic system on the internal environment, I wish to make clear the relation of emotional excitement to that environment. Already I have emphasized the point that the central control of the sympathetic system is to be found in the diencephalon—I need only refer again to Bard's evidence that the neural mechanism of sham rage has its locus in the hypothalamus. Under normal conditions, as we have already seen, the changes which take place in great rage or fear can be interpreted as useful adaptations of the body for vigorous struggle. It should be clear, however, that if no struggle occurs and an intense emotional state persists, the changes occurring in the body no longer are a preparatory safeguard serviceable in fighting or flight, but may be on the contrary profoundly disturbing. In present-day civilization we have many occasions for fears, anxieties and worries when there is no vigorous bodily reaction called for. The financier who watches the downward course of his

security-values or the waning of the returns from his investments, the applicant for a position who is about to undergo a severe physical and mental test, the mother who realizes that she has lost control of a wayward son or daughter, the anxious and responsible patient who faces a serious operation—all these cases illustrate the situations which may develop intense emotional turmoil in the body, when energetic action for defense or escape is impossible. The bodily adjustments characteristic of the emotional state appear, in their natural manner, but are now not only quite futile, but, worse than that, quite likely to be damaging.

We have seen that the faster heart beat and the heightened blood pressure from splanchnic stimulation are useful in the swift carriage of the respiratory gases—and that this change occurs both in vigorous exertion and as an accompaniment of fear or rage, which may be attended by the need for such exertion. But the sympathetic nerve impulses, which constrict the blood vessels of the splanchnic area and thus deprive the digestive organs of much of their blood supply, simultaneously inhibit the digestive functions which can not continue when the circulation is deficient. Thus, if this unitary sympathetic system is brought into action by strong emotions, there is not only the mobilization of the bodily forces previously described, but a stoppage of the beneficent processes of digestion. Cabot cites a case of a man whose broken leg mysteriously failed to knit. The patient, an ignorant foreigner to whom the hospital was an utterly strange place, had been left uninformed concerning the welfare of his family. After some time this fact was discovered, whereupon he was completely reassured. When this occurred, the normal course of repair began and continued to a satisfactory healing. The explanation offered for the phenomenon was that the anxiety and distress occasioned by fear for his family's welfare deeply interfered with the digestive and nutritive functions and thus retarded the bony union In the literature on diabetes there are many instances of the state becoming much intensified by emotional upsets such as rage and fright—an effect caused, no doubt, by sympathetic impulses. The best explanation of the sensitive heart—the "D. A. H." of wartime —is that it has its origin in emotional instability. These and other examples which could be cited are clear indications of the way in which the emotional level, by affecting the sympathetic system—the system in control of constancy of the internal environment—may have harmful influence on the organism as a whole.

Thus far we have considered the emotional level in lower centers of the brain stem as being under an inhibitory government from the cortex. The cortex is the agency of our voluntary acts. We have already seen that although the cortex can voluntarily check the expression of emotion in skeletal muscles, it can not directly influence the changes in viscera which are brought about by discharges from the diencephalon. This does not mean, however, that the cortex is not concerned with control of emotional situations The visceral changes produced in such situations may, to be sure, be conditioned reflexes, described by Pavlov, in which a direct and inborn stimulus for a certain act becomes, by association, related to the circumstance prevailing at the time the stimulus was applied. Thus, the ringing of a bell at the time food is given may result in establishing an association such that subsequent ringing of the bell causes flow of saliva. In much the same way, the involuntary bodily reactions which characterize emotional excitement may become conditioned by the circumstance which attended their appearance. Thus, during the war the banging of a door or

any other sharp noise would not uncommonly bring about a sharp sense of danger and raise a haunting fear in persons who had been sensitized by experience with a near-by shellburst. In a similar way, other pathological conditions can be accounted for. It is recorded that a wife who happened to see her husband walking with a strange woman on the street became greatly perturbed, and on rushing anxiously into her house found that her heart was palpitating in a distressing manner. The palpitation appeared whenever she ventured on the street. She was convinced that she was suffering from a disease of the heart, although her physician explained that there was no evidence of cardiac derangement. The case can be readily accounted for by a conditioning of the patient to publicity on the street by the emotionally upsetting incident which occurred there. There are many ways in which the cortex and the lower emotional level may interplay. I have touched upon only some of the more striking relations between the two levels.

Men engaged in medical practise, whether physicians or surgeons, have many opportunities to see ways in which strong emotions may upset the organism. I have cited disturbances of digestion, of metabolism and of the heart. There are still other instances which I might mention to show the influence of the emotional level. In conclusion, may I urge the propriety of recognizing where the organic seat of emotional disturbances is to be found. As we have seen, it lies in the ancient part of the brain—a part of the brain which we share with lower animals. It is a region where the primitive reactions of attack and defense have their source. It is associated with the functioning of the sympathetic division of the autonomic nervous system—a system which regulates body heat, which regulates blood sugar, which governs the acid-base relation of the blood, and it may be concerned with the water balance, fat metabolism and the phenomenon of sleep. Obviously, when this region is brought into activity, as is certain to be the case in strong emotional excitement, it may, as we have learned, deeply affect the internal environment of the body and thus determine for weal or woe the fate of the whole organism.

WHAT IS A FIFTY-POUND WEIGHT?[1]

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WHAT is a fifty-pound weight? A most simple query—naturally, a fifty-pound weight is a weight which weighs fifty pounds. But that answer is about as helpful to the uninformed seeker after knowledge as was the definition once given for "categorical syllogism" as "a syllogism expressed in categorical terms." Perhaps it is desired to know just what a "weight" is, just what is meant when it is said that something "weighs" so much, and, moreover, just what a "pound" is, anyway.

To provide satisfying answers to these secondary questions, it will be well to begin at the beginning and say first that the "mass" of a given body is the quantity of matter comprising it, and that so long as no portion of this body is removed and nothing is added to it, its mass remains constant. Now in the case of two masses, these attract one another with a force which is directly proportional to the product of their masses, and inversely proportional to the square of the distance between their centers of mass. The whole earth may be considered as one mass which will attract a body or mass at or above its surface; and the force of this attraction varies, in accordance with the general law just stated, directly as the mass of the small body and inversely as the square of the distance of its center of mass from the center of the earth. Due, however, to the rotation of the earth, a body moving with the earth is also acted upon by a centrifugal force which, in general, is greatest at the earth's equator and diminishes toward the poles. The resultant of these two forces—the attraction between the body and the earth and the centrifugal force due to the earth's rotation—is known as the force of gravity.

Determinations of the intensity of the force of gravity, made at different points on the earth's surface, show that at some points there are unexplained variations from the anticipated values; it is also found that the conformation of the surrounding terrane has an observable effect. In general, however, considering elevation alone, and positions on or above the surface of the earth, the force of gravity exerted upon a body is found to be very nearly inversely proportional to the square of the body's distance from the center of the earth; considering latitude alone, the force of gravity is found, in general, to be uniform for a given latitude, and to increase slightly and with approximate uniformity as the poles are approached.

From the foregoing it follows that if we can measure this force of gravity upon a given body, and if we can eliminate or correct for the effects of comparative elevation and of the other factors noted, we have at once a basis for comparing the mass of the body in question with the mass of any other body upon which we can similarly measure the force exerted by gravity. If we now express this measured force in terms of some acceptable unit, we are enabled clearly to define the mass of the body or

[1] Publication approved by the director of the Bureau of Standards of the U. S. Department of Commerce.

the amount of material of which it is composed.

The expression "weight" is used to mean a measure of the force of gravity exerted upon any body. This force or weight is measured by counterbalancing it with a similar force acting upon a body or bodies of known mass or with some counter-force of known value; when equilibrium is established, the two forces are equal, and the value of the previously unknown mass is thus directly or indirectly ascertained. The bodies of known mass are called "weights." The "counter-force of known value" may be supplied by a spring, a hydrostatic assembly, a "pendulum" scale assembly or otherwise, usually acting through a system of levers; in this case, the known value of the counter-force has been determined by resorting to weights. In other words, what we commonly call a "standard weight" is really a standard mass of metal or other material by comparison with which the masses of other bodies may be determined through measurement of their respective weights.

In commercial transactions involving quantity determinations, the important consideration is to determine the mass or the amount of commodity; since these determinations are made, however, in terms of weight, as just defined, the expression "weight" is loosely used to represent the amount of commodity. Thus "100 pounds of steel" really means a mass of steel such that the force of gravity exerted upon it is 100 times greater than the force of gravity which is or would be exerted, under the same condition, upon a standard mass known as the "pound." However, since the units of mass and weight are identically named, and since no practical purpose would be served in commercial transactions if the two were to be distinguished, the distinction between them may be considered of scientific interest and importance only, and the commercial usage in which the expression "weight" is used in the sense of "mass" need not be condemned.

In reference to the gravitational force acting on a body, it has been said that this is a function of the distance of the center of mass of the body from the center of the earth. The magnitude of the effect of a change of elevation upon the gravitational force exerted upon a given body is of the order of one part in 2,000 for a change of elevation of 6,000 feet, the "weight" being less the greater the elevation. But if we have weights which are standard according to some accepted basis, and use these on an "equal-arm" balance to determine the "weight" of an unknown amount of commodity, the accuracy of the result, upon the accepted basis, will be independent of the elevation at which the determination is made and check determinations made at different elevations should agree, because the change in the intensity of the gravitational force affects equally the standard weights and the commodity being weighed. The same would be true in the case of a weighing mechanism employing a compound-lever system. In any case, however, where a spring is utilized as the ultimate counter-force, disregarding other effects, different results would be obtained at different elevations, provided that the weighing mechanism were susceptible of indicating the differences actually existing. In the case of such a device, if the assembly is sufficiently sensitive to respond to weight differences resulting from a change of elevation, and if such differences of indication may be read upon the device in question, it should be calibrated against standard weights at the elevation at which it is to be used, thus making its indications standard for that

elevation. In the case of ordinary commercial devices, however, it is probable that these differences can never be observed, and in any event they are of such small magnitude, relative to the graduations on the commercial device, that they may be entirely disregarded.

Let us now proceed to a consideration of "What is a pound?" If we refer to the dictionary we find "pound" defined as "a unit of weight varying in value from about 300 to about 1,070 grams and commonly divided into 12 or 16 ounces." From this definition it would appear that the pound is not a very definite unit of weight. The dictionary further tells us, however, that the avoirdupois pound of 7,000 grains is used in this country in the weighing of most commodities, but that the troy pound of 5,760 grains is used in certain restricted fields of weighing. If we pursue our researches farther afield and endeavor to trace the history and determine the origin of the units which we know as pounds, we can go back, step by step, until we finally reach a point where recorded history ceases and beyond which we can not proceed for lack of authentic data.

As to the pounds of the United States we know, of course, that these came to us from England. As to the history of the English standards, the following is quoted from "Men and Measures," by Edward Nicholson, an English author:

Our pound [the Imperial pound of Great Britain] settled at its present Imperial standard in the time of Queen Elizabeth, was then found to have risen slightly since the time of Edward III. It was found to have increased by about 8 grains. The ounce, now = 437½ grains, had been 437 grains, the same weight as the ounce of the Egypto-Roman pound, the Roman libra. There is every reason to believe that this Roman standard passed to Britain, and that the libra, raised to 16 ounces, became the commercial pound, afterwards known as Averdepois, and now the Imperial pound.

When the Romans took the Alexandrian talent as the standard of their new libra-system, they divided it into 125 librae, which were 1500 ounces or double-shekels, each ounce = 437 grains.

. . . It is not improbable that the survival of the Roman commercial pound in Saxon England was strengthened by commercial and scientific relations with the Moors of Spain.

. . . However this may have been, there seems no doubt that the Roman pound, raised to 16 ounces, was the standard of England before as after the Norman conquest, and there is no evidence of it having ever been in abeyance . .

The same author gives a table of Roman weights reading in part as follows.

Libra = 5244 grains
Uncia = 437 grains
Drachma = ⅛ uncia = 54.6 grains
Scrupulus = ⅓ drachma = 18.2 grains

Here will be recognized certain terms and relations familiar to us in our present apothecaries' table. According to Mr Nicholson, the Roman ounce of 437 grains was in England taken 16 times to make the commercial pound of 6,992 grains, and to this pound 8 grains were subsequently added to give an even figure of 7,000 grains for the pound.

Considering the origin of the Roman pound we find that this, in common with other ancient standards of weight, was derived from a standard of linear measure. The principal ancient linear unit was the cubit. There were a number of these, the most important being the

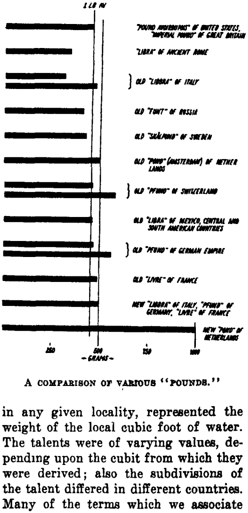
Egyptian common cubit of 18.24 inches, its foot being two-thirds of this or 12.16 inches.
Egyptian Royal cubit of 20.64 inches, its foot being two-thirds of this or 13.76 inches.
Great Assyrian cubit of 25.26 inches, its foot being one-half of this or 12 63 inches.
Beladi cubit of 21.888 inches, its foot being one-half of this or 10.944 inches.
Black cubit of 21.28 inches, its foot being two-thirds of this or 14.186 inches.

Speaking of these cubits, Mr. Nicholson says:

The history of the five cubits, ancient and medieval, has shown that they were all derived, directly or indirectly, from the Meridian measurement of the earth, some of them being probably instituted with the desire to make them representative of the relation of latitude and longitude

I venture to say that every measure and weight used throughout the world has been developed from one of these cubits. . . .

The principal ancient unit of weight appears to have been the talent which,



A COMPARISON OF VARIOUS "POUNDS."

in any given locality, represented the weight of the local cubic foot of water. The talents were of varying values, depending upon the cubit from which they were derived; also the subdivisions of the talent differed in different countries. Many of the terms which we associate with ancient monetary units were in reality primarily subdivisions of the talent as a weight unit.

This line of investigation might be pursued almost indefinitely, tracing the relationships between the various weight units of ancient times and their connections with units of the present day, but enough has probably been said to demonstrate that there is a direct connection between our present-day standards and those of very ancient times, both as to values and names. This mention of similarity of names for corresponding weight units suggests a brief excursion into the field of modern nomenclature. Mention has already been made of the Roman libra, a word which seems to be responsible for our present abbreviation of "lb." for pound. The Roman uncia, the Greek drachma and the Roman scrupulus have already been mentioned as the derivations of the modern ounce, dram and scruple. We find that in modern times the funt of Russia, the libbra of Italy, the libra of Spain, Portugal and various South and Central American countries, the livre of France and Greece, the pfund of Germany, the pond of Java and the Netherlands, and the pund of Denmark and Sweden, correspond to the avoirdupois pound, as we know it, although the exact equivalents in terms of our pound vary from about $\frac{3}{4}$ to over 2 pounds.

The development of the word "avoirdupois" is also interesting. We find this word variously spelled in old English documents as "Haberty poie," "Haberdepase," "Avoirdepois," etc. "Aver" is said to be an old established English word meaning "goods," and the combination in question is said to mean "goods of weight" or "heavy goods." Some of the old statutes refer to this pound as the one to be used for the weighing of corn, heavy goods, meat and fish, a distinction apparently being drawn between such commodities and more expensive commodities, such as spices, precious metals, precious stones,

etc., which were weighed in small amounts. By the avoirdupois pound, then, is meant the pound for heavy goods as distinguished from the troy pound used by the gold and silver smiths and in connection with the coinage. "Avoir" in modern French also has the meaning of wares or merchandise, so we can arrive at the same meaning for "avoirdupois" by considering the word as of French origin.

And now let us consider some facts about our own United States pound For a complete discussion of our standards, the reader is referred to the paper of Louis A. Fischer on "The History of the Standard Weights and Measures of the United States," published as Bureau of Standards Miscellaneous Publication No. 64. For our present purposes we need only sketch briefly the points which Mr. Fischer discussed in detail.

Colonial weights were of English origin and corresponded to those in use in England prior to the formation of the Colonies. There was considerable divergency, however, among the weights of the several colonies, and this persisted after the formation of the Union. Repeated efforts were made to have Congress correct this condition, but without success. Finally, in 1828, Congress decreed that a certain troy pound which had been procured in England, and which was supposed to be an exact copy of the imperial troy pound of Great Britain, should thereafter be the standard for the coinage of the United States. Two years later Congress ordered that a comparison be made by the Treasury Department of the weights at the principal custom-houses. Large individual discrepancies were found, but the average values for the different denominations were found in fairly good agreement with the weights used in England at the time of the Revolution. In order to construct uniform weights to be furnished the custom-houses, the Treasury Department found it necessary to adopt a definite standard; it was decided that the relation between the avoirdupois pound and the troy pound of the Mint should be as 7,000 is to 5,760, this being the relation previously accepted in the United States and in England.

Uniform standards having been furnished to the custom-houses, Congress in 1836 directed that copies of these be furnished the several states, and as additional states were admitted to the Union they were also supplied with standards; North Dakota, in 1893, was the last state to receive one of these sets.

In the year 1870 there was held in Paris a conference to which various nations had been invited by the French Government to send their representatives, to consider the advisability of constructing new standards of the metric system. This and subsequent conferences were attended by representatives of the United States, and these meetings resulted in the decision to construct new metric standards, and in the signing of a treaty providing for the formation and maintenance of an International Bureau of Weights and Measures. This international institution is supported by the various countries signatory to the treaty and is controlled by an elected committee upon which the United States has always been represented.

New metric standards having been constructed by a special committee appointed for that purpose, these were compared with the old metric standards by the international bureau, and at a general conference held in 1889 the new kilogram, which agreed most closely with the kilogram of the Archives, was declared to be the international kilogram; the other kilograms were distrib-

uted by lot to the various governments supporting the international bureau, the United States receiving kilograms Nos. 4 and 20. These were brought to this country in 1890, kilogram No. 20 arriving in January and kilogram No. 4 arriving in July. Kilogram No. 20 was accepted by President Harrison upon its arrival as the national standard, and both standards were deposited in the Office of Weights and Measures of the Coast and Geodetic Survey. On April 5, 1893, the Superintendent of Weights and Measures, with the approval of the Secretary of the Treasury, decided that the international kilogram would in the future be regarded as the fundamental standard of mass in the United States, both for metric and customary weights.

The Office of Weights and Measures used as the relation between the avoirdupois pound and the kilogram the equivalent, 1 pound avoirdupois equals 0.4535924277 kilogram, a value determined by the joint work of the International Bureau of Weights and Measures and the British Standards Office. When the National Bureau of Standards was established in July, 1901, the decision of the Office of Weights and Measures to recognize the international kilogram as our fundamental standard of mass, and the equivalent just given as the relation between the avoirdupois pound and the kilogram, were fully accepted by the Bureau and are so accepted to-day.

Earlier in this paper it was indicated that when we speak of a "standard" weight we mean a weight which is standard according to some accepted basis. The following statement represents the practise accepted in the United States as that upon which weights of Classes A, B and C are to be considered standard:

The calibration is based upon the apparent mass as determined at 20° C. in air having a density of 1.2 milligrams per milliliter, against standards having a density of 8.4 grams per cubic centimeter at 0° C., whose coefficient of cubical expansion is 0.000054 per degree Centigrade, and whose values are based on their true mass or weight in vacuo. The scope of this paper is not broad enough to permit of a discussion of each of the factors just mentioned. Those desiring to go somewhat into detail on these matters will find them discussed in Circular No. 3 of the Bureau of Standards, Design and Test of Standards of Mass.

To sum up, then, the situation in relation to the United States avoirdupois pound is this: The pound is defined in terms of the kilogram, the relation being 1 pound avoirdupois equals 0.4535924277 kilogram. The international kilogram, preserved at the International Bureau of Weights and Measures, Sevres, France, is our fundamental standard of mass; our national primary standard is the kilogram preserved at the Bureau of Standards, the value of this in terms of the international standard being known with the highest accuracy attainable by the modern metrologist.

The United States primary kilogram is used upon rare occasions to verify the accuracy of the reference standards of the mass laboratory of the Bureau of Standards, which, in turn, are utilized to check the accuracy of the laboratory's working standards. These latter standards are of various denominations, suitable for the comparison of weights submitted to the Bureau for test.

When examinations are made at the Bureau of the primary standards of weight of a state, the errors of those standards are determined and reported to the state in a certificate returned with the weights, so that the state may have in its possession authentic standards of known values with which to control its

own testing activities. The state primary standards are then used by the state to prove its secondary or office working standards, the latter are used in testing the field or inspectors' working standards, and the field standards are carried to the commercial establishments using weights or weighing equipment, there to be used in the final step of the long series of comparisons beginning with the International Kilogram and ending at the merchant's counter.

So now if a fairly concise answer were to be made to the original question of "What is a fifty-pound weight?" this might take the following form: A fifty-pound weight is an object, usually of metal, having such a mass that, when compared in air under specified conditions, the gravitational force acting upon it is just fifty times as great—within appropriate tolerances, of course—as the gravitational force acting upon a standard mass of specified characteristics known as the "pound," which is equal to 0.4535924277 kilogram.

SCIENTIFIC METHODS OF OYSTER FARMING[1]

By Dr. HERBERT F. PRYTHERCH

DIRECTOR, U. S. FISHERIES BIOLOGICAL STATION, BEAUFORT, N. C

IT is sometimes said that the oyster is found in nearly all bodies of water except the oyster stew. If such a doubtful condition did exist the oyster can at least plead "not guilty" and offer as evidence in his defense the 152 million pounds of oyster meats which he furnishes annually to the people of the United States. This would allow for each person approximately one and a quarter pounds of the most healthful food product harvested from the sea. Both the edible and non-edible portions of the oyster are of economic importance, the former yielding a return to the fishermen of $17,074,000 in 1929, while the latter or oyster shells converted into poultry feed and lime were valued at $2,524,499.

The first question of human existence is, "When do we eat?" to which the early inhabitants of our shores, the aborigines and Indians, must have frequently replied with appropriate grunts and gestures, "at low tide." Oysters and other shellfish could then be easily gathered from the natural beds on the tidal flats or in shallow water, and judging from the huge oyster shell mounds of ancient origin this bivalve was an important item on the bill of fare at their primitive feasts. In Maine, at the mouth of the Damariscotta River, one mound, containing over 8 million cubic feet of shells, was found as a great monument to the antiquity of oysters on this coast. In the near-by streams, the Sheepscot and George Rivers, the Indians apparently transplanted oysters from the Damariscotta to keep them alive near home, thus indicating the earliest evidence of oyster culture in America.

Oysters were a valuable food resource in the early struggles of the Pilgrim Colonists against starvation and deemed of sufficient importance at Plymouth for the passing of restrictive laws before the end of the seventeenth century for protection of the oyster beds. As time went on the natural beds were rapidly depleted, particularly those in the northern coastal areas, and led to earlier and greater developments in this section for producing oysters by cultivation.

Oyster farming has become an important industry on both the east and west coasts of the United States. By the use of modern scientific methods and equipment, the oyster farmer has greatly increased the production of this shell-fish, improved their quality and converted thousands of acres of useless bottom into valuable food-producing areas.

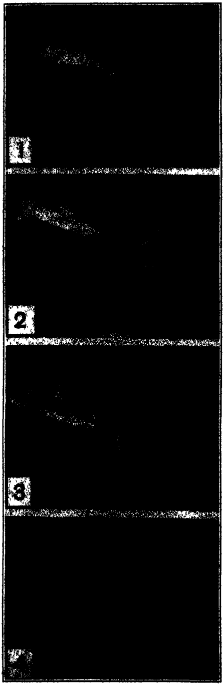
The commendable progress that has been made in this phase of aquiculture can be attributed largely to the gradual accumulation of more accurate knowledge concerning the oyster and its environment. Reliable information and facts of fundamental and practical value to the industry have been contributed by both oystermen and scientists. Oystermen have learned through their own experiences the value of experimental methods. In their own way they have conducted innumerable experiments, many of them costly, in order to find new oyster growing and maturing grounds or better methods for increasing production and improving the quality of their product. The early experiments in shell planting, transplantation of seed, deep-water culture, etc., served as

[1] Published by permission of the U. S. Commissioner of Fisheries.

a foundation and stimulus to the extensive, present-day developments in oyster farming. As these oyster cultural activities increased in magnitude it was found that similar results were not obtained from year to year, or in different localities, and that these expensive operations were more or less of a gamble each season. Nearly every oysterman had certain "pet" theories as to the principal factors controlling oyster growth and propagation, but these frequently failed as intelligent guides in oyster farming and involved considerable losses in labor and materials.

The leading men of the industry soon realized that the real facts concerning the oyster must be determined by scientific study in order that commercial operations might be conducted on a sound basis. In response to their requests numerous scientific investigations have been made of the oyster by research workers from the state and Federal departments of fisheries and public health and by individuals from universities and private institutions. Many difficult and important problems pertaining to the oyster and its environment have received the careful attention of the biologist, bacteriologist, chemist and nutrition expert. In our scientific studies we have made considerable progress and have discovered many essential facts concerning this shell-fish that are of practical value to the industry. Though such advances as have been made to date are but a beginning they have clearly demonstrated that research is one of the best forms of security for capital invested in the oyster industry.

Three species of oysters are being cultivated in the United States. The most important of these, *Ostrea virginica* or the so called "eastern oyster," occurs naturally on the Atlantic and Gulf coasts and comprises over 99 per cent. of the annual yield. On the Pacific coast intensive cultivation of the native



OYSTERS SPAWNING
1, 2, AND 3—VIGOROUS DISCHARGE OF EGGS BY THE FEMALE; 4—GRADUAL RELEASE OF SPERM BY MALE OYSTERS.

SETTING OF THE LARVAL OYSTER
1—SWIMMING LARVA PROTRUDING FOOT IN RESPONSE TO COPPER STIMULATION; 2, 3, 4 AND 5—LARVA CRAWLING AND TURNING ON SIDE OF DISH; 6—ATTACHMENT COMPLETED.

oyster, *Ostrea lurida*, and an imported Japanese species, *Ostrea gigas*, is carried on chiefly in the State of Washington. The oyster lends itself readily to cultivation, first, because it is unable to move of its own volition from the beds on which it is placed; second, because it can withstand rough handling and long exposure to air; and third, because of its interesting and unusual life history, which makes possible unique methods for controlling and increasing its production In the last 10 years the efficiency of cultural operations has been greatly advanced on the basis of information obtained from scientific studies of the more important stages in the development of the oyster, the physiological processes of the adult, the influence of environment conditions, etc.

Starting with the reproductive activities, research has shown that a single female oyster may produce under favorable conditions as many as 100,000,000 to 500,000,000 eggs during one season. Naturally the eggs are microscopic in size (1/500 of an inch in diameter) and occupy so little space that it would be possible to place in a one-quart bottle enough to supply our annual oyster crop of over 20,000,000 bushels. The fecundity of the oyster enables us to make further interesting calculations, *i.e.*, if all the eggs produced in our coastal waters during one favorable season were to survive and grow to market size there would be enough to cover the entire country with a layer of oysters over 30 feet deep. Egg production has been found to vary greatly, however, from year to year and sometimes when amounting to only a few million per oyster is insufficient to produce an adequate supply of spat or seed oysters. An annual fluctuation of only 10 million per oyster becomes significant, as it indicates that for each acre of adult oysters there will be a total increase or decrease of approximately 100 billion to 300 billion in egg production. In Long

Island Sound, the greatest oyster-farming region in the world, it has been possible to establish a direct correlation between water temperature (from April to July) and the success or failure of spawning and propagation of seed. When water temperatures are above normal during this period, egg production is greater and results in a proportionate increase in the supply of seed. For several years advance information and predictions along this line have been furnished by the Bureau of Fisheries as a guide to the oystermen in their expensive operations of planting shells and other materials for collection of seed. By taking advantage of the favorable years and planting a greater quantity of shells it has been possible to increase the supply of seed and adult oysters in these waters.

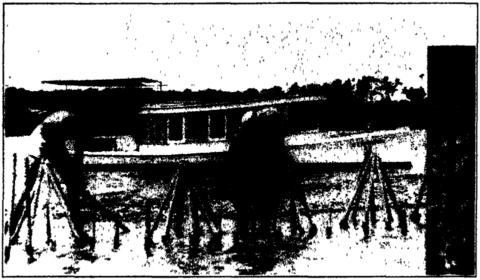
Studies of the spawning of the oyster show that water temperature and mutual stimulation of the sexes are the important controlling factors No spawning occurs below 20° C. Ripe males shed sperm at 20° to 24° C., while the spontaneous discharge of eggs by the female requires a temperature of 24.5° C or above. On the other hand, the spawning reaction may be induced at slightly lower temperatures by the addition of reproductive products of the opposite sex. Under natural conditions the males spawn first, and the process, once started, spreads by mutual stimulation of the two sexes throughout the whole oyster bed. To insure successful propagation of the species the oyster farmer establishes spawning beds where water temperatures are favorable and concentrates the plantings of adults so as to facilitate simultaneous spawning of the oyster population and increase the possibilities for fertilization of the eggs.

The time of spawning varies from year to year and in certain coastal areas has been found to occur during certain phases of the moon. Studies in Connecticut, North Carolina, South Carolina and Georgia show that these activities usually take place from 6 to 9 days after either full moon or new moon Indirectly the moon is responsible for spawning at such times because of its influence

DISTRIBUTION OF OYSTERS ON A PILE IN FOLLY RIVER, S. C.

SETTING OCCURS HERE ONLY ABOVE LOW WATER MARK AND CAN BE DIRECTLY CORRELATED WITH VARIATIONS IN COPPER CONTENT OF THE WATER.

on the tides and water temperature. The higher tides at times of full or new moon cause the water to pass over a greater area of tidal flats, where it absorbs, particularly during the early summer months, considerable heat from



PLANTING SEED OYSTER COLLECTORS NEAR BEAUFORT, N. C.
CEMENT-COATED, PAPER TUBES ARE SET OUT ON MUD BOTTOM NEAR OYSTER REEF TO PROVIDE PLACE OF ATTACHMENT FOR LARVAL OYSTERS. INSERT—SINGLE TUBE, 9 MONTHS LATER, COVERED WITH SEED.

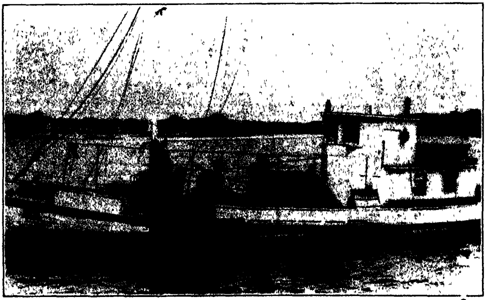
the land and sun's rays. During these periods increases of 8° to 10° C. in water temperature have been observed and can be correlated with spawning. By means of observations on range of tide, water temperatures and ripeness of oysters, it has been possible in Long Island Sound to determine approximately one month in advance when spawning will occur. In oyster farming this information has proved of considerable value and is now used by the industry for correctly timing the planting of seed-collecting materials. This is the most important operation in oyster culture and must be completed not later than two weeks after spawning, when attachment of the larval oysters occurs.

The development of the oyster from the egg to the stage when it sets or cements itself to some clean submerged object usually requires from 13 to 16 days. In 2 to 3 hours after spawning the fertilized egg develops into a swimming larva; in 20 hours it is completely covered with a shell and swims about gathering food by means of a ciliated disk-like organ or velum; in two weeks it has completed larval development and measures approximately one seventy-fifth of an inch in diameter. Just previous to this time the larva has formed a powerful foot for crawling and a large supply of sticky material by which it anchors and cements itself to an old shell or stone. In fact, the larva is not particular as to its choice of a future home and may attach to a discarded bottle, boat, tin can, auto tire or any convenient clean surface. In different oyster regions various terms such as setting, striking, spatting, catching and fixation are used to designate the attachment process, which is the most important and critical phase of the oyster's development. Both the survival of the oyster and the success of cultural operations depend largely on the ability of the larva to find and firmly immobilize itself on a suitable object.

Setting is usually completed in from 20 minutes to one hour, according to the

salinity of the water and requires a definite chemical stimulus for its initiation. Copper is the only known element that will induce this reaction and has a pronounced effect under natural conditions in minute concentrations of one part copper in 2 to 10 millions of sea water Surface and underground waters leach copper from the soil and transport it to the inshore coastal areas On passing into sea water the dissolved copper forms a colloidal precipitate (copper oxychloride) and in this form is taken into the digestive tract of the larval oyster. In about 4 minutes the larva begins the setting process and after crawling back and forth over the surface of some convenient object finally secretes a quick-hardening cement with which its shell is firmly attached to the substratum The oyster is now definitely fixed for the rest of its life or at least until some ruthless oyster tonger or cultivator knocks it off for market or for transplantation to other beds.

Cooperative experiments of the biologist and oyster culturist have shown that setting is heavier and occurs with greater regularity in certain inshore coastal areas. In many of these locations natural oyster beds existed in the past but have since been depleted by over-fishing and pollution. The oyster farmer has reclaimed and rehabilitated most of this territory by the establishment of spawning beds and now utilizes these bottoms for the collection of seed oysters Large quantities of shell are planted there at the proper time and gather in many instances many million more spat than can survive on the available surface. For example, a single shell oftentimes collects from a few hundred to several thousand spat, while there is only room enough for 25 or 30 to survive. With such intensive setting, a very high percentage (98 to 99 per cent.) of the spat die from overcrowding, lack of food, oxygen, etc.; and those surviving are so closely cemented to-



INTENSIVE SHELL PLANTING OPERATIONS ON SEED BEDS IN NEW HAVEN HARBOR, CONN.

BY PLACING SHELLS IN BAGS THE PRODUCTION OF SEED OYSTERS PER UNIT OF BOTTOM CAN BE INCREASED MANY TIMES.

gether and misshapen as to be of little value as seed oysters.

The loss of a large potential supply of seed under such conditions has been overcome to a great extent by (1) increasing the planting of shell during favorable years as described previously and (2) by the use of special spat-collecting devices. Several practical types of artificial collectors have been developed by the Bureau of Fisheries by which the yield of seed oysters on a given area of bottom can be increased from 10 to 50 times, as compared with the usual practise of scattering shells. For this purpose wire bags filled with shells, cement-coated partitions, tubes and expanded mats of waterproof paper have proved satisfactory. By planting these devices singly or in stacks it is possible to present a greater area of surface for the attachment of the oyster larvae and utilize the three dimensions of seed-producing bottoms. In one experiment in Milford Harbor, Connecticut, a planting of 7,000 partitions collected over 20,000,000 spat, while an equally heavy set was also obtained on the layer of shells over which they were placed. With stacks of shell bags it has been possible to collect spat on 8 or 10 bushels of shell per square yard, thus saving millions of seed that otherwise would be lost. The intensity of setting in bags planted in New York, Connecticut and Massachusetts ranged from 1,500 to over 65,000 spat per bushel of shell and was found to vary according to seasonal conditions, position of spawning bed and the particular tidal level at which the collectors were planted

In Southern waters, poles, brush and cement-coated tubes have proved to be satisfactory devices for gathering seed.

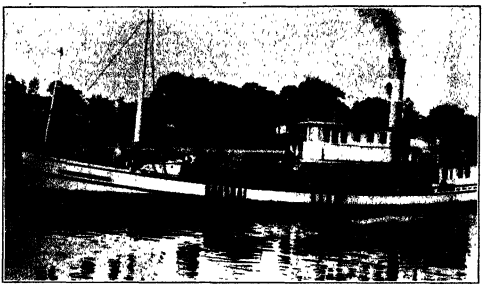
A REPRESENTATIVE CROP OF OVER 300,000 SEED OYSTERS
COLLECTED IN PARTITIONS IN MILFORD HARBOR, CONN. THE SEED ARE TWO MONTHS OLD AND READY FOR DETACHMENT AND SEPARATION BEFORE PLANTING ON DEEP WATER BEDS.

PLANTING PARTITIONS FOR COLLECTION OF SEED OYSTERS, CORE CREEK, N C.
SETTING OF OYSTER LARVAE MOST INTENSIVE IN ONE FOOT ZONE ABOVE LOW WATER MARK
INSERT—SINGLE PARTITION TWO MONTHS LATER COVERED WITH 3,000 SEED OYSTERS.

Numerous demonstrations and experiments of the Bureau of Fisheries have shown how collectors of this type are particularly suitable for use on soft mud bottoms and offer a practical means for utilizing thousands of acres of such areas for seed production. The brush and cement-coated collectors are superior in some respects to shell in that they remain clean longer and permit detachment and separation of the seed when a few months old. The latter procedure has been found to increase the growth and volume of the oysters nearly 100 per cent. during the first year and also produces a desirable type of shell that will withstand the rough treatment of dredging and transplanting operations. By the use of improved spat collectors and more accurate planting of shells as to time, place and quantity, the oyster farmers have efficiently utilized the prolific setting areas and have overcome the serious scarcity of seed that confronted the industry a few years ago.

In the fall or spring the seed oysters are taken up and transplanted to selected growing grounds. These areas are generally located in deeper water where setting does not occur, and consequently oysters placed there are not covered and overcrowded by successive generations On these grounds the seed oysters are given ample room for growth and reach marketable size in from two to five years, according to the locality in which they are grown. In some cases the oysters are transplanted a third time to areas where food and water conditions are excellent for fattening and will increase the volume and market value of the meats.

On the Pacific coast in the vicinity of Olympia the oyster-growing bottoms have been improved and enlarged by the construction of an elaborate system of concrete or wooden dikes. The tidal slopes are divided into a series of one acre ponds, arranged at several different levels and retaining enough water at low tide to cover the oysters. Though the construction of dikes and improvement



TRANSPLANTING A BOATLOAD OF YEAR OLD OYSTERS
FROM THE INSHORE SEED BEDS TO SELECTED GROWING AREAS IN LONG ISLAND SOUND.

of enclosed bottoms involves an investment of $1,000 to $3,000 per acre, this type of oyster farming is highly successful and yields from approximately 10 to 45 times greater returns than any other crop (corn, oats, potatoes, cranberries, etc.) cultivated in the State of Washington.

CRUSHING PLANT IN OPERATION AT BEAUFORT, S. C.,
FOR CONVERTING OYSTER SHELLS INTO POULTRY FEED AND LIME. OVER 347,000 TONS OF THESE PRODUCTS, VALUED AT $2,595,252 WERE PRODUCED IN 1930.

Studies of the feeding of the oyster have had an important bearing on these operations in respect to the relative density of plantings for growing and maturing purposes. The oyster is a heavy drinker, especially during the warmer months, when he pumps through his gills over 15 gallons of water per day from which is extracted practically all the oxygen and suspended food materials. Some idea of the magnitude of this process can be gathered from the fact that the oysters in our coastal waters consume in the aggregate approximately 10 times as much water daily as is used by the entire population of the United States in the same period of time for domestic purposes. The oyster farmer applies this knowledge by limiting the number of oysters planted per acre according to their size and age and the relative quantity of water circulated over the beds by the tides and currents. Records of his past experiments in the cultivation of different areas are also used as an index of their potential value for growing or fattening oysters and are of considerable aid in determining the correct density of planting for each particular bed.

OYSTER GROWERS AND BIOLOGISTS INSPECTING A DREDGE LOAD OF SHELLS FOR EVIDENCE OF SEED OYSTERS (SPAT). INCREASED SHELLING OPERATIONS, BASED ON PREDICTIONS OF THE BIOLOGIST, PROVE SUCCESSFUL.

In the fall and winter as the water temperature becomes lower the feeding activities decrease and stop entirely below 6.7° C. (44° F.), when the oyster goes into a state of inactivity or hibernation. In the north the hibernation period usually extends from November until April and is an important factor in insuring the purity of the oyster and improving its condition for marketing and transportation. The oyster farmer, in harvesting his crop in the cooler

weather from his selected maturing Health the sanitary quality of the oys- beds, brings the oysters to market when they are in the best possible condition Bureaus of Chemistry and Public ters and the waters in which they are Through the work of Federal and State grown is carefully supervised and guaranteed by standards equal to those used for milk and drinking water Some concerns go still further and treat their oysters before shipment in chemically purified sea water, which greatly improves their sanitary and keeping qualities through destruction of bacteria and spoilage organisms.

The final step in the preparation of oysters for market is the shucking or removal of the meat from the shell. This laborious and expensive process, exceeding in cost all other oyster-farming operations and involving an annual expenditure of over $1,500,000, has also received scientific investigation.

The chief difficulty in shucking an oyster, that of gaining admission to the shell, has been overcome by putting the oyster to sleep in a harmless narcotizing solution of acidified fresh or salt water A small amount of acid, such as acetic, hydrochloric, etc., reacts with the shell carbonates producing an excess of carbon dioxide which in turn induces relaxation of the oyster muscle with automatic opening of the shell.

Continuation of these studies at the U. S. Fisheries Biological station at Beaufort, N. C., show that the time required for opening can be reduced from several hours to a fraction of an hour by jarring or hitting the oysters before treatment. By a combination of physical and chemical agencies it is now possible to open bivalve shell-fish with less expense and labor and also improve their sanitary condition.

With the present trend of national events it may prove advisable to employ ethyl alcohol for narcotizing and opening oysters, as our investigations show it to be particularly suitable for this purpose. Whereas the American Indian solved this problem with the use of fire, the modern oyster farmer may go him one better and employ "firewater" to facilitate removal of the live meat of this delicious shell-fish.

HOW RIVERS CUT GATEWAYS THROUGH MOUNTAINS

By Dr. DOUGLAS JOHNSON

PROFESSOR OF PHYSIOGRAPHY, COLUMBIA UNIVERSITY

If one crosses the Appalachian Mountains, as, for example, when traveling from the Ohio Valley eastward to New York or Washington, he will find his path obstructed by a great series of parallel, heavily forested ranges. They seem almost endless, and the Indians actually called them the "Endless Mountains," the Alleghenies If travel is by automobile, one may occasionally climb obliquely up one of the steep mountain slopes to the crest, there to get a magnificent panorama of the Endless Mountains, range following range like the waves of an angry sea. But more frequently, and particularly if travel is by train, one will turn north or south along one of the parallel valleys between the ranges, until he comes to a gap or gateway cut right through the mountain barrier These gaps provide some of the most beautiful scenery of the Appalachian Mountains: The Hudson Gorge in the Highlands of New York, sometimes called the Rhine Valley of America; the Delaware Water Gap at the boundary between New Jersey and Pennsylvania; the water-gaps of the Susquehanna north of Harrisburg; and the water-gap of the Potomac at Harper's Ferry (Plate I), where Union troops were stationed throughout most of our Civil War to guard that strategic gateway into the fertile lands of the Shenandoah Valley.

As the traveler passes through one of these remarkable gaps, in going from one side of a mountain range to the other, he may notice two very significant things: First, that there is a river flowing through the gateway, often a great river like the Hudson, the Delaware, the Susquehanna, the Potomac or the James. Second, he may notice that the walls of the gateway are composed of extremely hard rocks, often in layers which are tilted up at a steep angle. After having crossed through several of these natural gateways, and repeatedly observed the same general relations, the inquisitive traveler may be tempted to do a little geological detective work on his own account. He may conclude that the mountain range is there simply because a layer of unusually hard rock was not worn down as low as weaker layers on either side And he may also conclude that the river is there because in some way the river itself carved the gateway through the hard-rock mountain ridge. If he does reach such conclusions, he will have made a good beginning toward unraveling the greatest geological mystery of the Appalachian Mountains.

But it will be only a beginning. For notice this remarkable fact: The great rivers of the Appalachian region, instead of following the weak-rock layers between the resistant ridges, flow directly across one hard-rock barrier after another. Instead of taking easy courses from northeast to southwest, they take the hardest possible courses, from northwest to southeast directly across the most formidable mountain ranges in the eastern United States. This is the great mystery of the Appalachians. Why do the larger rivers flow across the rock structures, instead of parallel to them on the more easily eroded layers?

From the earliest days of geological

PLATE I. WATER-GAP OF THE POTOMAC RIVER

THROUGH THE BLUE RIDGE AT HARPER'S FERRY. PHOTO BY FRANK SMART, U. S. GEOLOGICAL SURVEY

study in America this peculiar feature of Appalachian drainage has aroused much interest, and various explanations of the water-gaps have been advanced. Some observers offered the romantic explanation that during the deluge described in the Bible, when Noah and his Ark sailed the waters of the deep, great waves hurled gigantic boulders against the mountain barriers until openings were broken through them. Others believed that fracturing of the earth's crust, such as produces most of our earthquakes, made lines of weakness in the hard-rock ridges which rivers could then easily widen into the water-gaps as we see them. One author avoided the difficulty very neatly by by saying that rivers flowed along until they came to openings in the mountains, whereupon the rivers turned and went through these openings. Apparently in his mind the water-gaps were like Topsy —they "just growed" that way. A more complicated explanation, and one accepted in earlier days by many geologists, supposed that the rivers acquired their present courses long before the mountains came into existence. Then the earth's crust was wrinkled so very slowly that the rivers were able to cut down their channels just as fast as the mountains were uparched across their paths. The majestic gorge of the Columbia River through the Cascade Mountains, the Royal Gorge of the Arkansas in the Rocky Mountains (Plate II), and even the Grand Canyon of the Colorado in Arizona have by some been explained in this way. According to this theory the rivers are very much older than the mountains they cut across.

It is very true that rivers are often among the very oldest features of our landscapes; and that the hills and mountains, although truly "rock-ribbed," as the poet tells us, instead of being "ancient as the sun," are relatively transient features of the earth's surface, often washed away completely in the course of time. But the geologist has discovered serious objections to the theory that Appalachian rivers are older than the mountain ranges across which they flow, just as he finds serious objections to all the other theories mentioned above. It is quite possible that no one has yet discovered the true explanation of the mysterious behavior of these rivers in flowing directly through one hard-rock barrier after another. But I venture to present the latest interpretation of this peculiar feature of Appalachian scenery, the one which seems best to explain all the facts known to us.

In outlining this latest theory one must go far back in earth history and repeat some things upon which all geologists are agreed. Where the Appalachian Mountains now stand there was, millions of years ago, a great shallow sea, stretching far westward to and beyond the position of the present Rocky Mountains. Rivers brought gravel, sand and mud from adjoining land masses to deposit them in this shallow ocean basin, and lime was deposited from the oceanic waters. At times the deposits filled parts of the vast basin, changing such areas into extensive plains on which the rivers continued to spread their deposits, and over which extended broad swamps filled with beautiful tree ferns and other tropical vegetation. The gravels, sands, muds, lime and swamp deposits, when hardened and otherwise altered, became the conglomerates, sandstones, shales, limestones and coal beds which we find in the Appalachian region to-day. In the shales and limestones are abundant marine shells of very ancient pattern; and in the coal beds, trunks and roots of trees, and graceful impressions of the fronds of ferns.

Then came a great change. The long repose of the inland sea and plain gave place to a slow but relentless crushing of the earth's crust. From southeastern

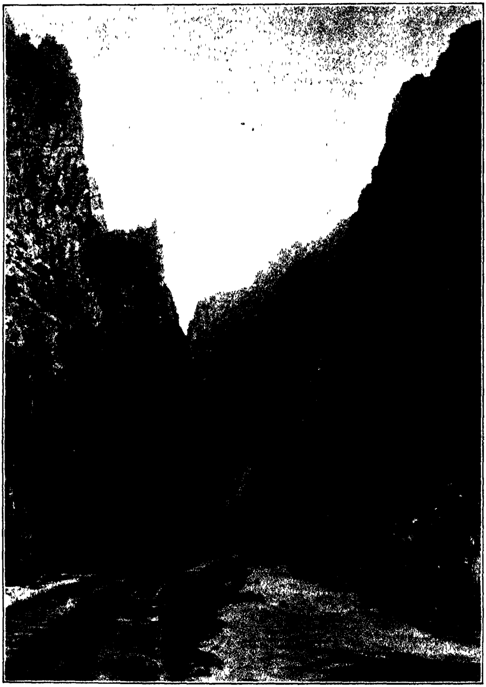


PLATE II. ROYAL GORGE OF THE ARKANSAS RIVER
A GATEWAY CUT THROUGH ONE OF THE ROCKY MOUNTAIN RANGES IN COLORADO. ACCORDING TO ONE THEORY, THE RIVER WAS HERE FIRST. THE MOUNTAIN RANGE WAS LATER UPLIFTED ACROSS ITS PATH, BUT SO SLOWLY THAT THE RIVER WAS ABLE TO CUT DOWN AS FAST AS THE MOUNTAIN MASS WAS UPARCHED. PHOTO BY DOUGLAS JOHNSON.

FIG. 1. A SLICE OF THE EARTH'S CRUST

CUT ACROSS THE APPALACHIAN MOUNTAINS AS THEY ARE SUPPOSED TO HAVE APPEARED MANY MILLIONS OF YEARS AGO.

FIG 2 THE ANCESTRAL APPALACHIANS

AS THEY APPEARED AFTER MILLIONS OF YEARS OF STREAM EROSION HAD REDUCED THE MOUNTAINOUS REGION TO A LOW-LYING PLAIN NEAR SEA-LEVEL.

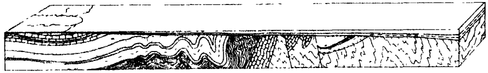


FIG 3 THE FORMER MOUNTAIN REGION

IS COVERED BY THE ADVANCING SEA, AND BY THE DEPOSITS OF SAND AND MUD ACCUMULATING ON THE SEA BOTTOM.

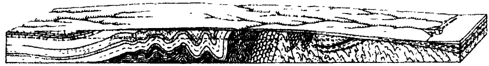


FIG. 4. THE APPALACHIAN REGION

IS RAISED OUT OF THE SEA, AND A NEW SYSTEM OF RIVERS FLOWS SOUTHEASTWARD (TO THE RIGHT) DOWN THE SLOPING SURFACE OF THE SEA-BOTTOM DEPOSITS.

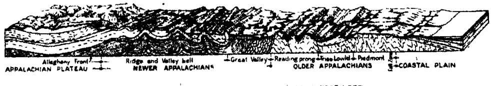


FIG. 5. THE PRESENT APPALACHIANS.

THE SEA-BOTTOM DEPOSITS HAVE BEEN REMOVED BY EROSION, EXCEPT FOR A REMNANT AT THE SOUTHEASTERN (RIGHT) END OF THE SECTION. RIVERS HAVE ERODED VALLEYS ON WEAK ROCKS, LEAVING HARD ROCKS STANDING UP AS MOUNTAIN RIDGES. THE MAIN RIVER PERSISTS IN THE COURSE EARLIER ACQUIRED (FIG. 4), CUTTING WATER-GAPS THROUGH THE RIDGES.

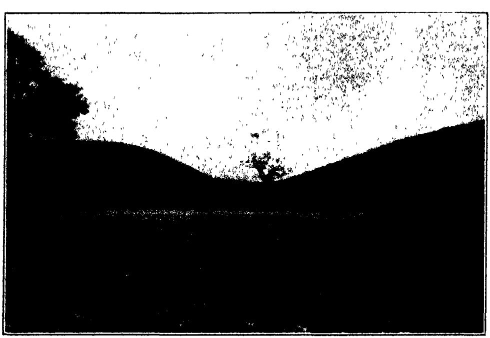


PLATE III. WIND-GAP NEAR PEN ARGYL, PENNSYLVANIA
IT IS BELIEVED THAT THE UPPER PART (NORTH BRANCH) OF THE SUSQUEHANNA RIVER FORMERLY FLOWED SOUTHEASTWARD THROUGH THIS GATEWAY, WHICH IS NOW ABANDONED BY THE STREAM THAT CARVED IT. PHOTO BY DOUGLAS JOHNSON.

Canada to the Gulf of Mexico a broad belt of the former sea and land deposits was upheaved and thrown into gigantic folds or wrinkles, the ancestors of our present Appalachian Mountains (Fig 1).[1] Down the slopes of these mountains, and along the hollows between them, the falling rains collected in brooks and rivers. We shall not concern ourselves with these very ancient river courses because, according to our best evidence, all these streams were later completely destroyed, and have nothing whatever to do with the present courses of Appalachian rivers.

If you ask the geologist when it was that the flat-lying beds of the inland sea and plain were crumpled up to form the Appalachian Mountains, he can tell you on the basis of abundant reliable evidence that it must have been many, many millions of years ago; probably somewhat more than 200 million years, although he can not fix the time with any degree of accuracy. But he knows it was so extremely long ago that the rains and rivers, each day washing some small part of the mountains into the sea, had ample time to wear all the high ridges of the ancestral Appalachians down to a low plain near sea-level. The rivers still persisted on the low plain, but only the roots of the mountain folds were left (Fig. 2).

Then occurred the most dramatic event in the long history of the Appalachians, an event which, as we shall see, explains the mystery of the water-gaps. Slowly the low plain was bent down under the sea to the east. Slowly the

[1] All diagrams used in this article are from the author's volume on "Stream Sculpture on the Atlantic Slope," and are reproduced by the permission of the publisher, Columbia University Press, New York City.

Atlantic Ocean crept in over the down-bending plain, past where Boston, New York and Atlantic City now stand; past the present positions of Albany, Philadelphia, Baltimore, Washington and Richmond; still further west, far past Harrisburg, Harper's Ferry and Charlottesville, Virginia; so far west, indeed, that most of what had been the mountainous region was now covered by the sea (Fig. 3). Where the rivers formerly flowed, now rolled the ocean waves. The entire drainage system of the early Appalachians was blotted out completely, and the roots of the ancient mountain folds were buried under deposits of sand and mud laid down on the new sea floor.

Again conditions changed Slowly the sea bottom, with its deposits of sand and mud, was raised out of the ocean waters, with a strong slant downward toward the southeast. On this slope an entirely new series of rivers was born (Fig 4). Since the upraised sea bottom was inclined downward toward the southeast, the rivers flowed in parallel courses down this slope; that is, from northwest to southeast. The steeply tilted hard-rock layers were, of course, still left in the roots of the old mountain folds. But since they were completely buried under the new sea-bottom deposits of sand and mud, they could not in any way influence the new drainage system. Thus it happened that while the hard-rock layers underground all trended from northeast to southwest, the rivers developing on the overlying cover of sea-bottom deposits all flowed in exactly the opposite direction, from northwest to southeast across the buried ridges.

The rest of the story is easy to understand. The rivers cut deeper and deeper into the cover of sand and mud, until they found themselves flowing across the hard-rock ridges below. Once starting to cut in that position, they could not easily change their courses, and so continued to cut deep notches into the resistant rock Meanwhile, further erosion washed most of the cover of sand and mud back into the sea. Branch streams developed on the weaker layers of the underlying folded rocks, and wore them down much lower than the hard-rock ridges The main streams continued their original southeast courses across the mountain barriers, and the notches cut by them became known as "water-gaps." Even where a main stream has since been diverted to some other course by important geological events, its former pathway across the mountain barrier is often clearly marked by a "wind-gap" (Plate III) A wind-gap is a notch or gateway similar to a water-gap, except that the stream which carved it no longer flows through it

We have, I think, found a reasonable solution for the mystery of Appalachian drainage It explains why the mountain ranges have one direction, and the main rivers an entirely different direction. It explains why the mountain ridges are found to be merely the stumps of great folds, which formerly rose many thousands of feet higher than the ranges we actually see to-day. And it explains how the rivers could cut spectacular gateways through the very hardest rock in these mountains. Delaware Water Gap, and other water-gaps of the Appalachians, are not merely forms of exceptional scenic beauty. They have the added charm of an origin dating millions of years back in the remote geologic past, and testify to sweeping changes of land and sea during a history full of truly marvelous events.

THE CHACHAS OF ST. THOMAS

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ALMOST every visitor to the United States Virgin Islands is interested in the small group of white French Chachas[1] who live in St. Thomas (Fig. 1). These fisher and farmer folk furnish such a contrast to the large colored element in the population that one can not help being curious about who the Chachas are, where they came from and what they are doing on an island which belonged to Denmark for over two centuries and only sixteen years ago was purchased by the United States. It is the purpose of this article to answer these questions and to indicate the influence of geographic environment on the manner of living and occupations of this little French colony.

The Chachas are a group of French peasants, numbering about nine hundred, who form a separate and distinct element in the life of St. Thomas. They differ from the colored people, who make up 87 per cent. of the inhabitants, in race, language, customs and major occupations With their tanned ruddy faces the French stand out conspicuously among the large number of black Negroes. When one hears the Chacha speak, the French patois[2] serves to emphasize his distinctiveness, for the language sounds strange after listening to the colloquial English of the colored. Customs set the French apart even more definitely Unlike the Negroes, members of the little colony have married only with their own clan and have kept their racial purity for generations. This characteristic is an unusual one in the West Indies; in fact, white colonies who have maintained the purity of their race through a long period of time are far from common in any section of the tropics. Finally, one group of the French colony account for most of the fishing of St. Thomas; they are good fishermen and boatmen, and although most of their canoes are crudely made, the Chachas handle their craft well and one seldom hears of accidents. The other group of French are farmers. They make their living under trying conditions, all their land is in slope, and some of it is so steep and stony that one wonders how the farmer engaged in tilling the soil can keep his balance

Different stories are told of the Chacha emigration to St. Thomas. It has been said that they are descendants of French Huguenots who fled to the Virgins after the revocation of the Edict of Nantes. La Bat,[3] an early French writer on West Indian lands, indicates that in 1701 two small streets in St. Thomas town were occupied by a group of French refugees. The group to whom La Bat refers were no doubt Huguenots, for a few descendants of these trades people, who always lived in the port of St. Thomas, yet remain. These descendants, however, are not Chachas, and the fact that all Chachas are Catholics throws extreme doubt on any story that their ancestors were early French Protestant emigrants. Another tale suggests that their ances-

[1] The French received their name from the Negroes. The English-speaking colored people could not understand the French patois and indicated that it sounded like "chacha" to them That name has clung to the French ever since in spite of their dislike to it.

[2] Many of the Chachas speak and understand English as well as French.

[3] Pere La Bat, "Voyage aux Isles de l'Amérique," Vol. II, p. 285.

tors came from St. Croix after the French sold the island to Denmark in 1733; this seems improbable, for the French deserted St. Croix in 1695 and, after burning their houses, sailed for Santo Domingo A final version indicates that the Chachas are descended from French people who left the islands of St. Bartholomew and St Kitts after the middle of the nineteenth century, and came to St. Thomas because they thought they would better their economic situation by the change

It is known that in 1866 two young Frenchmen by the name of La Place sailed from St. Barts and settled on the north side of St. Thomas[4] Others came from the little French island later and the descendants of these emigrants make up the agricultural Chachas to-day. Moreover, there is authentic evidence that many of the fishing colony came from St. Bartholomew or are descendants of emigrants from St. Barts. In fact, reliable authority makes safe the assumption that all Chachas are descendants from colonists who came from Brittany in early days and settled on St. Barts and other French Caribbean isles before coming to St. Thomas less than a century ago

[4] Joseph A Kimm, "Mafohe," *The Angelus*, November, 1931, Baltimore, Maryland.

THE CHACHA FISHERMEN

The fishing group who live at Carenage, a suburb of St. Thomas adjoining the city on the west, came from a long line of fishermen. Before leaving Brittany for the Caribbean, the European ancestors of the Chachas no doubt gained some of their living from the sea. Their occupation was encouraged by a plentiful fish supply in near-by waters, numerous bays and inlets of a submerged coast-line which provided fishing bases, and the lack of favorable economic opportunities on land When the Bretons came to St. Barts, again physical factors guided several into the fishing

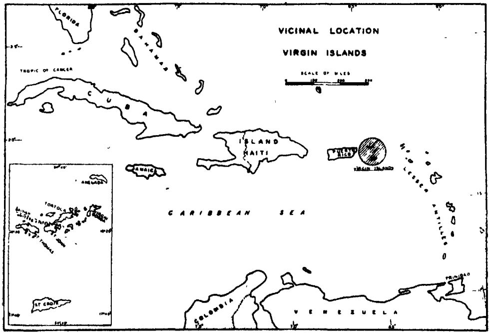

FIG. 1. VICINAL LOCATION OF THE VIRGIN ISLANDS

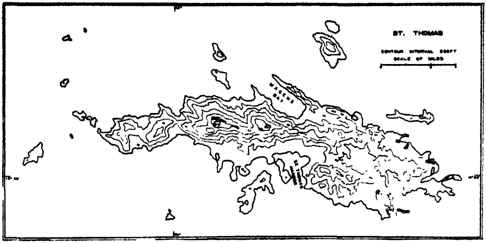

FIG 2. TOPOGRAPHIC MAP OF ST. THOMAS

industry. The rugged topography and inadequate rainfall discouraged farming, while submarine banks surrounding the island provided an ideal environment for fishing. Finally, when the descendants of the Brittany emigrants left St. Bartholomew and sailed for St. Thomas many continued to follow the industry of their fathers because the indented shore-line, the wave-cut shelves, the submarine platform and an inhospitable environment for farming—all were features that called the new Virgin Islanders to the sea.

To-day the French use the little bay fringing their town of Carenage, a suburb of St. Thomas, as a fishing base. From here they row and sail their small boats throughout the banks area which extends seaward for several miles from the shore-line of St. Thomas. In fact, the submarine platform upon which St. Thomas rests is merely a portion of the larger platform that supports Puerto Rico, Vieques, Culebra and all the Virgin Islands, with the exception of St. Croix. The water above this bank and the wave-cut shelves which bound its inner margin is comparatively shallow; and the slight depth aids in the mechanics of fishing Moreover, an abundance of sunlight penetrates to the shallow submarine floor, and provides a necessary element in the formation of plankton which gives food for the fish. The numerous bays and inlets of the submerged coast furnish storm protection for the fishermen and make easy the capture of fish, many of which seek the quieter waters. The forest vegetation, found on parts of St. Thomas, affords materials for fashioning traps, trap marker buoys, buoy lines, turtle decoys, a few of the boats and some of the other equipment used by the workers. The local vegetation also supplies a portion of the bait for attracting the catch. Finally, the steady trade winds drive the semi-sailboats on one leg of the fishing journey. These major geographic factors aid the fishing of the Chachas.

The Chachas peddle most of their fish from house to house and sell them by the strap. The strap, a piece of heavy grass or reed, takes the place of a string; and French fishermen with several bright-colored fish strung on these reeds may be seen on the streets of St. Thomas almost any time of the day. The price varies with the hour of sale—in the

morning it is higher than in the afternoon; for in a warm climate the fish deteriorate rapidly without ice, which the Chachas find too expensive to buy.

Fishing does not yield enough income to provide a fair standard of living. Hence, the women folk weave certain of the indigenous palms and grasses into attractive basketry, hats, mats, brooms and other articles and sell their handiwork to local buyers and tourists. Even with this supplementary income some families lack sufficient means for the necessities of life; and rumor goes that several of the men resort to "bootlegging" in order to add to their meager funds. "Bootlegging" should not be a difficult occupation in St. Thomas. The source of liquor is near—Tortola, a British island a few miles to the northeast, is "wide open"; the numerous bays and inlets of the submerged shore-line provide good hiding places from prohibition agents; and the people of St. Thomas hold the eighteenth amendment in no greater awe and reverence than do people in continental United States. All these factors would favor any Chacha who dared supplement legitimate with illegitimate occupation.

The Chacha Farmers

Crop agriculture is a hard taskmaster in St. Thomas, yet three or four hundred Chachas gain the major share of their income by this type of farming. St. Thomas has a very rugged topography; a mountain backbone extends in a general east-west direction throughout the island's length, and north-south spurs branch from the axial range in several places—in some areas reaching the coast (Fig. 2). Probably not more than four or five hundred of the total of eighteen thousand acres could be called arable. Upon this topographic background, and with thin soils affording little agricultural aid, the industrious French produce their crops of vegetables and fruit. In spite of the slight encouragement that nature has given them on land, they have chosen a money crop there rather than risk the harvest of the sea, like the Chachas of the port city. True, the north side French supplement their farming by sustenance fishing, but crop agriculture remains their major occupation, and terracing, necessary in some places, calls for intensive culture. However, the gardens do not involve the terracing of entire hillsides, as is the case in some parts of the world where steep slopes of hundreds of acres are cultivated by patient workers; but here small plots containing fifteen or twenty terraces, each several rods long and a few yards wide, spot the general background of woodland vegetation.

Geographic factors have influenced the choice of farm location Limited

FIG. 3. ROCKS IN CHACHA GARDEN
THE FARMER HAS CLEARED THE VEGETATION FROM HIS LAND, BUT HE MUST YET PILE ROCKS AND TILL THE GROUND BEFORE PLANTING.

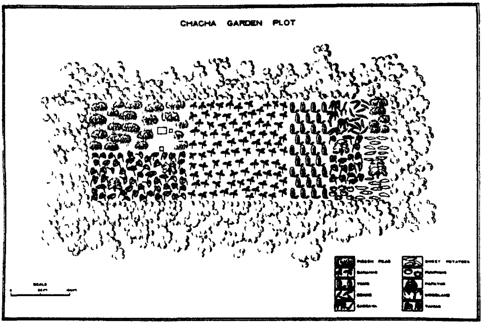

FIG. 4. CHACHA FRUIT AND VEGETABLE PLOT

moisture has always been a significant handicap to agriculture in St. Thomas as well as in the other Virgin Islands, so that the thrifty farmer is careful to locate where maximum precipitation occurs. Northern instead of southern slopes are chosen, because the former lie to the windward of the northeast trades, and where elevation is sufficient there is a noticeable advantage in rainfall. Furthermore, the north slope permits less exposure to the sun, an important factor in an area where evaporation is as high as it is in this trade wind zone. The farms are not favorably situated in reference to the St. Thomas market, but the moisture advantage outweighs the handicap of distance.

None of the land is suitable for machine cultivation, as mechanical equipment does not work well on land with a high angle of slope and on ground that is covered with stones (Fig. 3). Moreover, the small size of the plots and the poverty of the farmers are also limiting factors. Here and there boulders of several tons defy removal, but the worker picks off the smaller rocks and uses them in his terracing. However, he must clear off the brush growth before piling the stones; so with the machete, the all-purpose tool of the Caribbean, the first stages of gardening begin. After the vegetation is removed and the outer edge of the terraces buttressed, each rock-bordered plot is given a thorough preparation before any seed are planted. The machete is not discarded entirely in making ready the seed bed, but the versatile knife yields its importance to a heavy mattock-like hoe, better suited to removing roots and tilling the soil.

Planting may take place at any time of the year, although February, March and April are the months of lightest rainfall; few farmers risk this dry season to start crops except near the close of the period. During the early summer, convectional rains usually provide

ample moisture for the fruits and vegetables, and in late summer and fall the hurricane influence furnishes bountiful precipitation.[5] A variety of crops are grown, and when the ground is covered with vegetation the little farm looks like a miniature patchwork quilt (Fig 4). The Cavendish banana, which is grown in preference to the Gros Michel or other large species because of the lesser moisture requirements, occupies about one third of the space There is a tendency, where possible, to utilize low-lying ground in order to take advantage of greater water supply and the fresh soil materials that are washed down from steeper slopes above. Terracing is seldom practised in raising bananas. Root crops take a large share of the remaining area; first among these are tanias (Fig. 5), tropical tubers which taste like potatoes, although the large elephant-eared leaf has no resemblance to the potato vine; second, one may see the sweet potato, a drought-resistant vegetable well adapted to St Thomas environment; following in order are pigeon peas, yams and cassava, with smaller areas of onions, tomatoes, egg plants, peppers, okra, turnips, cabbage and lettuce. Not all crops are grown by each farmer, for the last named vegetables are not easy to raise; yet no garden is without tanias, bananas, sweet potatoes and pigeon peas. Very few Chachas attempt growing corn. Although a critical influence, deficient moisture, is not the limiting factor; instead, diseases and insect pests, which are a problem in raising nearly all tropical crops, so handicap the maize that the French have given up its planting. It is not necessary to distribute crops, so that tall bushy plants like pigeon peas occupy sections to the windward of the garden. This custom is followed in many places of the tropics where vegetation has been cleared over large areas; but here a general background of second growth woodland protects the garden spots from the desiccating effects of the northeast trades.

Marketing offers almost as many problems as production. There is little opportunity for export, as size of industry, lack of standardization and quality of produce, inadequate transport and storage and keen competition from regions with better physical backgrounds restrict outgoing shipments. Furthermore, the neighboring islands of St. John and Tortola (British) compete for the one home market, St Thomas City. Finally, since the Chacha gardens are from three to five miles to the north of St. Thomas on the other side of the mountain range, delivery is by no means a simple task The distance would be negligible were topography smooth and good roads available; but the highways are steep, rugged mountain trails, best fitted for donkey transport; and these little animals may be seen every day carefully picking a path along the narrow rocky way which leads from farm to market (Fig. 6). A boy[6] is usually hired to attend to the delivery and sale of the produce; the farmer has little time himself, for the task involves the greater part of the day, and he must keep busy tending his crops. Moreover, help may

[5] Sometimes rainfall is too heavy for these steep slope gardens. The writer visited this section on one occasion after an extremely heavy downpour, and the storm had played havoc with many of the terraces, the water washing large gullies through the cultivated land. The industrious French were zealously repairing the damage as best they could.

[6] The boys have peculiar signals which they employ to control the donkeys. One sounding like the yodeling of a "b'rrr" is the queerest the writer has ever heard. He met a pack train guided by one of the Chacha boys at a narrow section of the mountain road to St. Thomas one day. The lad called out a yodel that, while mirth-provoking to the listener, was very effective as a command, for the donkeys immediately turned the way the driver desired them to go.

FIG 5. TANIAS

THE TANIA IS A ROOTCROP HAVING AN EXTREMELY LARGE LEAF (THE VINE IN THE IMMEDIATE FOREGROUND IS NOT A TANIA VINE). THE HIGH ANGLE OF SLOPE OF THE CHACHA FARM MAY BE SEEN IN THIS PICTURE.

be obtained cheaply, especially at the present time when unemployment prevails in St. Thomas just as it does almost everywhere else throughout the world. Yet the same situation that brings about a plentiful labor supply encourages low prices for produce, and after paying his hired help, the farmer has a shockingly small amount left.

When prices are too low, the Chacha gardener turns to the sea, although he seldom, if ever, depends on fishing except for local sustenance. Some supplement crop raising by keeping a few chickens,[7] which furnish a desirable food supply and provide a surplus of eggs. These are carried to market in grass-packed baskets, a striking contrast to the modern egg case of the continental United States poultryman. On a few farms cows add to the family income. Donkeys, so useful in delivering fruit and vegetables, transport the milk to the city where it is peddled from house to house.[8]

Thus by versatility and hard work the Chacha gardener manages to make a living in spite of many handicaps. Moreover, his natural French thrift enables him to save money out of the small returns from his produce. In fact, several have bought their own land, and only a few years ago a company of thirteen purchased a tract of nearly three hundred acres. Contrary to general real estate practise, the purchasers paid for the whole in cash—in bills, silver and gold which they had taken out of hiding place—in earnings which they had been accumulating for years. The ground, the house or some similar hoarding place is the Chacha "bank." They have little faith in banking institutions and point to a recent local failure to justify this feeling. However, French "safety boxes" are not exactly secure; for at times when hurricanes have destroyed their houses these banks disappeared with the storm.

CHARACTERISTICS COMMON TO BOTH FISHER AND FARMER FOLK

Chacha Houses

The houses of the Chachas are not gorgeous mansions like the luxurious "great houses" of the early colonial sugar planters. In fact, some people might characterize the little French

[7] Chickens are hard to raise, however, for the mongoose takes a heavy toll. This animal was brought to the island to rid it of snakes and rats, but has proven as great a pest as the creatures which he has eliminated.

[8] Early in the morning donkeys loaded with boxes of bottled milk, a box on either side and a boy seated in the middle with his legs dangling over the animal's neck, may be seen on the streets of St. Thomas. The unpasteurised milk is sold in long-necked bottles with stoppers made from leaves.

dwellings as shacks, although the majority have a neat well-kept appearance in spite of their small size and modest construction. In general, they are built of wood and covered with galvanized roofing, a roof type quite common in the Caribbean region. With but two or at most three small rooms and no cellar or basement, the Chacha homes provide little extra space for the large families so characteristic of these people.

Simple in plan and construction, all houses are kept scrupulously clean. The Chachas zealously practise the precept that cleanliness is next to godliness, and they neglect neither of these characteristics. Cleaning is simplified by the fact that there are no carpets to sweep, no rugs to beat and no windows to wash. A special house cleaning is administered just before Christmas and the walls, generally covered with newspapers and religious pictures, are decorated with fancy garlands which are left up until well into the next year. The French rely on local resources for many of their household necessities. The maran, *Croton astroites*, provides soap; the skin of an alewife fish makes a good substitute for a scrub brush; and the leaves of indigenous palms furnish materials for brooms and mats. Local environment also contributes to their furniture. A few of the well-to-do may have a mahogany four-poster bed. Both bed and mattress may be made from island vegetation—the bed from the mahogany trees, which now have almost disappeared, and the mattress from bed grass or from the widely used banana leaves which yield ideal packing when dried and stemmed. But four-posters and mattresses are only for the more prosperous, and the rank and file have simpler bedroom furnishings. Father and mother may sleep in a bed, but each child, and often the parents, sleeps in a simple hammock made out of fish net material without even a bar piece at the head. A few chairs, a plain bench and perhaps a small table make up the remaining furniture.

Chacha Food

Like the house and furnishings, the food and manner of cooking is relatively plain and simple. Most families prepare their meals in charcoal pots placed on the dirt floor of an outside kitchen, or resting on three stones just beyond the house. The stones may be obtained easily anywhere, and the charcoal may be made from wood secured from the cutover forests. The preparation of the meal outside the house, a custom characteristic of most families of the Virgin Islands, saves the living quarters from heat and the odor of cooking food.

FIG. 6. CHACHA WITH DONKEYS LOADED WITH PRODUCE

THE DONKEY IS THE CHACHA'S "DELIVERY WAGON." THESE SURE-FOOTED CREATURES ARE WELL SUITED FOR THE TRAIL TRAVEL BETWEEN FARM AND MARKET. THEY TAKE BUT LITTLE CARE AND FEED AND ARE NOT SO PARTICULAR ABOUT THEIR FOOD AS THE HORSE.

The meals of the fisher folk consist mainly of fish, fungi,[9] and "soups" and "teas" often made from indigenous plants The farmers, however, have a better balanced diet. They may eat fish and fungi, but all have fruits and vegetables and some have milk and eggs This variety gives them a nourishing ration, which is reflected in the more robust appearance of the agriculturist class In eating their food, the organized family meal, which is common within continental United States, is extremely unusual. In general, Chachas eat separately; one may eat on a bench, another on the doorstep, and others may stand or sit in the yard while eating their food. They almost never congregate at a table for a meal, but carry their own little bowl[10] or plate around with them and help themselves from a common vessel of food.

Chacha Clothing

The clothing of the Chachas would distinguish them from the rest of the population, even though other differences were lacking. The women pay little attention to the whims of fashion, and consistently wear calico gowns and petticoats which reach well down to the ankles. The "cotta" and the kerchief, characteristic features of the Negro dress, are missing from the Chacha women The French do not need the "cotta," for they seldom carry a head load, and they will have none of the big kerchief around their shoulders. On their heads the Chacha women wear high-crowned, home-made straw hats, broadly banded with black and carrying a narrow drooping brim. The men are also dressed in neat, clean, simple attire. The hats, while showing masculine features, do not differ greatly from the high-crowned straws of the women. Furthermore, the straw headgear, fashioned by hand from the indigeous grasses and palms, matches well with the clean, colored shirts and narrow-legged pants or overalls which make up the remainder of their attire.

[9] Fungi is a gruel made largely out of cornmeal The meal is imported, for it can be shipped in cheaper than corn can be grown and prepared.

[10] Some eat their meal from calabash containers, which may also be used for drinking cups. The calabash is an indigenous tree, *Crescentia cujete*.

Chacha Religion

All Chachas are religious. The fishing colonists attend a Catholic church situated in the higher part of their little town of Carenage The agriculturists recently built a chapel near Mafolie estate to the north of the port and near the crown of the mountain divide. Both buildings are modest structures, and the severely plain benches and latticed altar rails carry out the idea of simplicity so characteristic of the community. The French children go to Catholic schools, although ample facilities are available at public institutions. In fact, on the north side some of the Chachas walk a mile or more past a public school on to the Catholic chapel and school at Mafolie.

Conclusions

In spite of an environment endowed with few economic opportunities, the industry, patience and thrift of the Chachas enable them to make a modest living. The similarity in physical background between several features of Brittany, St. Bartholomew and St. Thomas no doubt influenced the fisher folk to follow the occupation of their forbears. In carrying it on they made use of available geographical advantages—the banks, the inlets and harbors, the trade winds and the local resources that provide them with much of their fishing equipment. The harsh farming

conditions of St. Thomas, not dissimilar in many ways to those of St Bartholomew and Brittany, have failed to daunt the agriculturally inclined workers. They too have been guided by geographic principles in their arduous work. The location of their farms on the windward side of the mountain, the distribution of the crops in their gardens, the buttressing of the terraces with the plentiful supply of stones and the utilization of animals adaptable to the marketing of their produce—all indicate a tendency to take advantags of local geographic resources. Further geographic adjustments may be seen in the Chacha mode of living, in the character of their house, food and clothing: the plainness of their dwellings is a response to limited economic opportunity, their food is sharply influenced by their occupations and island resources, and the simpleness of their attire is an outward expression of their simple frugal life.

Unlike the Negroes, the Chachas offer few problems to the United States Government. If all the people of St. Thomas were as industrious as the French, the island resources would yield to a maximum; if the colored people were as thrifty as the Chachas, fewer favors would be asked of a paternal government; if the sex morality of the Negroes were as strict as that of the French, there would be less illegitimacy and a smaller percentage of mixed population. In short, the Chachas afford a constructive example to both natives and outsiders They have made a living in a hard environment by means of pluck and hard work and with little help from outside; and they have maintained rigid sex standards and racial purity in the tropics—a task some believe impossible

THE INTERNATIONAL STATUS AND OBLIGATIONS OF SCIENCE[1]

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In 1796, Britain being then at war with France, a French scientific sailor, Chevalier de Rossel, a prisoner of war in England evidently on parole, dined with the Royal Society Club in London on the invitation of Alexander Dalrymple, the hydrographer to the Admiralty. The Navy, as well as the Royal Society, clearly regarded scientific standing as entitling its holder to civilized and friendly treatment, regardless of the misfortune of a state of war between the two countries.

Among the instructions issued by the Admiralty to the captain of H. M. S. *Rattlesnake*, in which Huxley sailed in 1846 as "a surgeon who knew something about science," was the following:

> You are to refrain from any act of aggression towards a vessel or settlement of any nation with which we may be at war, as expeditions employed on behalf of discovery and science have always been considered by all civilized communities as acting under a general safeguard.

These short extracts from relatively modern history provide a text for this lecture. Science and learning have for several centuries been regarded by all civilized communities as entitling those who follow them to a certain immunity from interference or persecution—provided that they keep to the rules. You will notice that in both instances the Admiralty appears; they were chosen particularly for that reason. Sailors are apt to be friendly and chivalrous people, but also they realize—as the Admiralty has realized in its long association with the Royal Society of London—that such practical matters as lives and ships depend in some degree upon science, discovery and invention. In the second place, I would emphasize that this view of the position of science in the world at large does not involve any lack of pride in, or affection for, one's own country, that there is in fact as much to say for it from the point of view of old-fashioned chivalry as from that of modern internationalism. Science is a common interest of mankind: whatever the barriers or the difficulties or the struggles between them, civilized societies have accorded a certain immunity and tolerance to people concerned with scientific discovery and learning.

Why should science be singled out in this way? Merely by an ancient privilege based on an aristocratic and capitalistic tradition? Certain Russian colleagues, attending an international congress in London in 1931 on the history of science, made a vehement and mass protest against the claim that the progress of scientific ideas as such deserves a better place in general historical study. According to them science must be regarded not for its own sake but simply as the handmaiden of social and economic policy; probably they would protest even more vehemently against my present claim that in a certain sense science and learning are superior to and above the state. I would not, as a matter of fact, be ashamed to base an argument in part upon an aristocratic idea, for in science all men are not equal, any more than they are in strength, in courage or in goodness; but although histor-

[1] Huxley Memorial Lecture, Birmingham, November 16, 1933.

ically privilege may have had something to do with the tolerance shown to science, there is a much better reason for the safeguards given it by decent nations. The reason is that its methods of thought, its direct appeal by experiment to a universal nature, the new powers given to mankind in general by its application, so obviously do not depend upon the opinions, or emotions, or interests of any limited group that any civilized people will admit that it transcends the ordinary bounds of nationality. Religion, literature, art depend in part upon customs, emotions, race, climate, age and sex. The religious instinct, the artistic sense, may be universal enough, but their expressions can be so different that they may lead sometimes to strife rather than cooperation. In science, however, although mistakes are common and much that is published had better have been burned, although controversies are frequent and deplorable, although vanity and self-interest may hinder scientific progress as they may any other form of human endeavor, one fact remains certain. As all who are acquainted with the history of science and its present world position know, its discoveries do gradually build up a structure which is approved by all sane men; in the last three hundred years the experimental method, which is universal, has produced results beyond all previous human achievements. It is this universality of its method and results which gives science a unique place among the interests of mankind.

Science may be grossly misapplied, whether in making poison gases for war or in poisoning the decent sense of mankind. There are biologists who believe, or speak as though they believe, that the only effective biological principle is that of the "survival of the fittest." Following this narrow creed, a year or two ago Sir Arthur Keith delivered a rectorial address to the students at Aberdeen in praise of hatred and "prejudice" and in exaltation of war as a biological process. There are professors of war in Germany who do the same to-day, appealing in their case to historical and not to biological myth. It is sad that the tribal prejudices of so sweet and humane a nature as Keith's should tend to bring science into contempt, to remove the just basis for its privileged position: for biology does not teach what he supposes it teaches. Any physiologist who regards the living animal as a whole, after surveying in detail the functions of its several parts, is impressed by the extraordinary extent of coordination of those parts and functions. The further he explores the more intricate and perfect do the adjustments and adaptations appear. The differentiation of function, which has made the higher animals possible, has led to an extreme degree of cooperation between the different organs themselves, ensuring the well-being of the animal as a whole. The brain and the muscles, the pancreas and the liver, do not normally war against each other in order to ensure the survival of the fittest! What is true of a single creature is true also of a community. Indeed, it is often impossible to say where individual ends and community begins. The chief principle, therefore, in biology, the principle which differentiates it fundamentally from physics, is that the living organism is stable and self-perpetuating, within wide limits of treatment or environment, owing not to incessant struggle, or tribal prejudice, but to the exquisite integration, coordination and cooperation of its parts.

When, therefore, a biologist wishes to draw a moral, or to preach a sermon, from the principles of his science, let him take this as his text, and not the crude old nonsense that war, national hatred and national prejudice are biological necessities: otherwise, not only will he give to others the occasion to stumble,

but he will bring himself and his colleagues and their biology into disrepute.

I have dealt with this example, and made this protest, at length, because it serves to introduce a moral. If scientific people are to be accorded the privilege of immunity and tolerance by civilized societies they must observe the rules. These rules could not be better summarized than they were 270 years ago by Robert Hooke. Among Hooke's papers in the British Museum, Weld records a statement, dated 1663, which was probably drawn up after the passing of the Second Charter of the Royal Society. It begins as follows.

> The business and design of the Royal Society is—To improve the knowledge of naturall things, and all useful Arts, Manufactures, Mechanick practises, Engynes and Inventions by Experiments—(not meddling with Divinity, Metaphysics, Moralls, Politicks, Grammar, Rhetorick or Logick.

and continues

> All to advance the glory of God, the honour of the King . . , the benefit of his Kingdom, and the generall good of mankind.

Not meddling with divinity, grammar or rhetoric! To avoid such meddling is one price the scientific man must pay for his immunity. not a very heavy one, perhaps, though times come, as at present, when it is difficult not to meddle with morals or politics.

Scholars and scientists possess varying degrees of capacity in practical affairs. One disadvantage of prominence in any calling is the fact that the world, at least its newspaper reporters, is apt to believe that the views of the prominent person are of importance in matters altogether unrelated to his special capacity. The views of Bernard Shaw the Jester are quoted on politics or science: Soddy, the Chemist, writes fantastically about economics. famous astronomers get entangled with divinity or metaphysics. No doubt it is to be desired that Shaw should take an interest in science and Soddy in economics: preferably a reasonable and not an emotional interest: my contention simply is that their views need not be taken more seriously than those of more ordinary people. The most distinguished of mathematical physicists of to-day, Einstein, recently proposed at the Albert Hall that a place where young mathematicians could work undisturbed might be found in lighthouses· one pities the poor sailors who would depend upon their lights!

Newton, shortly before his death, is reported to have said—it were well if others had the same modesty.

> I know not what I may appear to the world, but to myself I seem to have been only like a boy playing on the seashore and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered be-

It is true that many distinguished scientists have been men of great general capacity; a man of such capacity is likely to be distinguished at any task he undertakes. The converse, however, is certainly not true; many of the most important contributors to science have been extreme specialists—rather dull dogs: others have been dreamers, poets, artists, rather than men of broad understanding. Their views on general topics may be entertaining, but they demand no special attention.

Not meddling with morals or politics: such, I would urge, is the normal condition of tolerance and immunity for scientific pursuits in a civilized state. I speak not with contempt of these—indeed the scorn with which some superior people talk of such necessities of social existence as morals and politics seems to me intolerably childish and stupid. The best intellects and characters, not the worst, are wanted for the moral teachers and

political governors of mankind; but science should remain aloof and detached, not from any sense of superiority, not from any indifference to the common welfare, but as a condition of complete intellectual honesty. Emotion, entirely necessary in ordinary life, is utterly out of place in making scientific decisions. If science loses its intellectual honesty and its political independence, if—under Communism or Fascism—it becomes tied to emotion, to propaganda, to advertisement, to particular social or economic theories, it will cease altogether to have its general appeal, and its political immunity will be lost. If science is to continue to make progress, if it is to lead to the advancement and not to the destruction of human institutions, it must insist on keeping its traditional position of independence, it must refuse to meddle with, or to be dominated by, divinity, morals, politics or rhetoric.

It is not always possible to avoid such meddling—as the life of Huxley showed. Much of Huxley's time was spent in battling with prejudice, in countering the attacks which were made upon the freedom of science to come to its decisions solely on scientific evidence. The traditional views of divinity, metaphysics and morals, aided by the resources of rhetoric, appeared in array against the Darwinian hypothesis and against evolution in general. Huxley realized the necessity of insisting on the independence of science, on the need of eliminating all other considerations in coming to scientific conclusions; and he knew—what all good fighters know—that offense is the best form of defense. He carried the war into the enemy's country so effectively that—apart from the vested interest of anti-vivisection—there has been in Great Britain no attempt to persecute scientific research and opinion for half a century. The world, and his country in particular, owe to Huxley a great debt for the freedom he won for science and scientific thought.

Such freedom, however, though fairly and hardly won, is not a permanent and inevitable attribute of science. At intervals it has to be maintained by further struggle. Like all great achievements of mankind, unless there are some to watch and guard, it may be destroyed in a night. The attachment of certain branches of science to competitive industry, desirable enough within limits, if it went too far might lead to the control of such science by industrial interests. The necessity of science in modern warfare might in some future Thirty Years War give it a purely national instead of an international basis. Its use for propaganda might prostitute it before the world. The coercion of scientific people to certain specified political opinions, as in Russia, Germany or Italy, may lower the standard of scientific honesty and bring science itself into contempt. Economic necessity may—it already does—so force young men, for reasons of advertisement, to unnecessary and premature publication, that the international burden of scientific literature may become top-heavy and unstable with disastrous consequences. These possibilities must be watched, and from time to time some champion of scientific independence must stand out, like Huxley, to do battle for freedom.

The present emergency—it can not fail to be in your minds—is that of the scientists and scholars in Germany who have been persecuted, or dismissed, for reasons of race or of independence of opinion. We are witnessing to-day, all over the world but particularly in Europe, an extraordinary phenomenon, the growth of a peculiar kind of "nationalism." The word "nation" is old enough, but the thought—or rather the emotion—which it arounses now is new. Since the dawn of history Europe has had its tribes, its village communities, its cities, its confederations, its kingdoms, its republics, its empires. It is in the process of developing—in many cases rather of

inventing—its nations. Unfortunately, neither blood nor language nor religion, nor continuity of territory affords any basis for the definition of a nation, and many of the difficulties of Europe to-day are due to the impossibility of deciding which nation is which. Now nationalism, like love of family, is a good thing when tempered with reason Nobody seriously grudges the Scot his little jokes about Scotsmen, or the Devonian his boasts about Devon; the Californian, the Virginian and the New Englander all have their local conceits and prejudices, but these do not prevent them from working together as reasonable beings To make your town or community happier, wiser or more prosperous, is a decent and worthy ideal, as I hold, it is worthy to try to maintain the traditional hospitality of England to those in other countries who are persecuted for causes other than crime When, however, nationalism leads to excesses of the kind we have seen in the last years, particularly in the last eight months, not alone in Europe, but all over the world, when violence and hatred are preached as its necessities by otherwise decent people, then indeed one begins to think of nationalism not as a pleasant virtue but as a hideous disease.

As a natural reaction, of course, to nationalism, we see internationalism developing Internationalism needs no more to be flabby and without character than the puritanism of the seventeenth century or the movement of the nineteenth to abolish slavery. One needs not to have a low opinion of one's own country to appreciate the virtues of others. Those who dislike war most—as the students who went from our universities in 1914 showed—are often the best fighters. The tendency to internationalism is displayed in the growth of international law. International finance, if its operations were large enough, might tend to promote agreement rather than strife. Travel results, in general, in less ignorance and bigotry, though it must be admitted that there is a type of ignorance and bigotry which returns home even more ignorant and bigoted than before. In literature and art internationalism first made itself felt. To write the history of any literature would be impossible without account of its foreign indebtedness. If the phrase "the republic of letters" is appropriate, "the republic of science" merely expresses a commonplace. International congresses, international measures of natural constants, geographical and navigational data and to-day radio (though that, alas, can be used also for fostering nationalism) are signs of the common interests of reasonable people in different countries. It can only be a matter of time before engineering standards, currency, and even some social customs, are much more uniform than to-day.

Another tendency, fostered by the same conditions, is to religious and political toleration. Earlier in the lifetimes of some of us still comparatively young, progress in this direction seemed inevitable; persecutions had fallen out of fashion. Even the Jews, whose history for centuries had been full of blood and tears, whose name had been a byword and reproach, had been admitted to all the rights of citizenship in all civilized countries. Violence, like drunkenness, was becoming disreputable. The last few years, unfortunately, have seen a reversal of "progress" in this respect at least, and gentleness has ceased to be admired: communism, and its natural—its inevitable—anti-body, fascism, have taken charge of the minds of a large section of human society—religious and political toleration is on the wane.

It needs no historian to recall how learning, scholarship and art, on the one hand, and natural philosophy and technology, on the other, have from early days been largely international in their

scope. In the western world, torn often with cruel and useless struggles, these were the only common interests of mankind. It is pleasant to remember how philosophers and scholars could, usually without hindrance, even in time of war, continue uninterrupted their intercourse with other countries. A document now more than 700 years old records the presence at Padua of French, English, Norman, Provençal, Spanish and Catalan students. Later at Padua 22 "nations" were represented, 12 from Italy itself, 10 from beyond the Alps. In the fifteenth century there were about 100 French students there, nearly as many English and Scottish, over 300 German. In spite of all difficulties of transport and communication there was a very real international sense in the humane pursuit of learning. Had learning and science had no other gifts at all to offer to mankind, their habit of transcending language, nationality and prejudice would have made them, more perhaps than anything else, worth while

Religion should have played, and sometimes actually did play, this part; too often, however, it was associated with the bitterest struggles of all. The persecutions of the Huguenots in France continued for nearly three hundred years; the last serious persecution was as late as 1815. The Edict of Nantes, which has been described as "one of the most flagrant political blunders in the history of France," caused, it is estimated, in a few years, the loss of nearly half a million citizens—citizens who, when assured of liberty of conscience, always showed themselves loyal and desirable subjects. Many of these emigrated to England and Prussia, where they contributed greatly to the commerce and culture of their adopted countries. The present persecution and emigration of German scientists are closely parallel to those of the French Huguenots.

The growing interest in science led in the seventeenth century to the foundation of societies and academies; those of London, Florence, Vienna and Paris were started about the middle of that century, that of Berlin in 1700. These academies, by their friendly relations with foreign scientists—the Royal Society published a large part of the writings of Leeuwenhoek and also of Malpighi—did much to uphold the superiority of science to national frontiers. One effect of this, however, was an increased use of the native tongue in scientific communications, instead of Latin, and this proved an obstacle to scientific intercourse. At the present time, in some countries, national pride rather than ignorance of a foreign tongue insists on publication in languages unknown to the majority of scientific workers. The spread of nationalism acted in the same direction. France, for example, in recent years has been singularly unwilling, perhaps unable to realize the need, to send her young men to study in foreign countries—with the result that in most subjects her science has lagged behind that of England, Germany and America, and even of some of the smaller countries of Northern Europe.

Increasing ease of transport to some degree compensated the abandonment of Latin as a common language. As communication, however, became easier and education more wide-spread, one might have expected that the common interests of mankind would have been more evident than they were. It almost seems to be true that the gods, when they offer one gift, send with it some counter gift to plague mankind. Nationalism in its present embittered form, spreading like a cancer over the earth, is one consequence of the very forces which one might have hoped would have made people realize their common humanity. A tinge of education, instead of making people more reasonable, seems to render them an easier prey of unscrupulous

propaganda, more subject to the hysteria of mass suggestion. If one's only form of literature is the cheaper press, with its appeal to emotion rather than intelligence, it is little wonder that one should be led, contrary to reason, into emotional absurdities. It would not be difficult for a cynical observer, experienced in neurology, to find exact clinical parallels to those hysterical outbursts of nationalism which make all attempts at a reasonable solution of world problems so difficult These disorders of mind and emotion have spread themselves by the imperfections of the very factors which—one hoped—would render them less likely. Never before were wars on so national a scale· never national hatred so widespread, national illusions so obstinate. I was at Stockholm once when a famous Irish poet, who had accepted all manner of kindness in England, caused great annoyance among his hosts there by his continual public references to England as "the enemy." Anti-semitism in France, culminating in the Dreyfus case, was a disgrace of which Frenchmen do not care to speak—it ruined the French Church, it nearly ruined France Yet it was nothing to the excesses of anti-semitism in Germany to-day.

If there be one single idea which, by common consent and with common applause, represents the contribution of England to the common welfare, that idea is freedom—freedom of action, freedom of belief, freedom of thought and speech The American Commonwealth was founded by English people on the same idea. Often, it is true, Englishmen have sinned, sometimes grievously, in this respect, but a jealous tradition, on the one hand, and bitter experience, on the other, have kept their country on the whole the freest in the world.

Now freedom, like health, may be a citizen's birthright, but it needs safeguarding. It is easy to allow bad habits to creep in unobserved, to tolerate a weakness or disease in its earlier stages until it gains too firm a hold. Freedom, like physical fitness, requires a constant effort. Those who will not fight for freedom do not deserve to be free. We can not trust to the victories of our forefathers: we must be ready—as Huxley was ready—to take part in the conflict ourselves

When I accepted the invitation last January to give this lecture I had intended to speak of science—as to some extent I have spoken—as a common link between the different races of men, as a means of promoting international understanding. To thinking people the progress of knowledge, the advance of medicine, the improvement of health and happiness which can be—should be—the result of scientific and technical achievement, are among the major interests of mankind. It seemed that nations and governments were certain, gradually, to realize this, and so would encourage co-operation, at least in intellectual things Private agencies have contributed very generously in recent times to this end. University College, London, for example, has been greatly aided by gifts from the Rockefeller Foundation to medical science and to biology, and to me alone in the last ten years that organization has sent about twenty fellows of ten different nations to work there. I know how much friendliness has been produced by the intercourse so made possible A few years after the war two other such fellows—a Belgian who had served in the Belgian armies in the field, and a German who had served in a German submarine—worked side by side with Starling there: without any disastrous consequences! All over the world, not only in education and in fellowships, but in field investigations of such diseases as yellow fever and malaria, the Rockefeller Foundation has been contributing (to use the terms of its charter) to the welfare of mankind throughout the

world. Their work is done, not in any religious fervor, not with flowery language, but as a matter of ordinary business and common sense—not meddling, as Hooke wrote, with divinity, morals, politics or rhetoric. The voluntary migration of hundreds of young scientists under the auspices of the Rockefeller Foundation recalls the movements of earlier times among the universities of Europe The Rhodes scholarships, the Commonwealth Fund fellowships, the Guggenheim fellowships, serve similar ends All these are bound to affect—I know that they have greatly affected—the outlook of the younger generation of scientific workers, these at least, however good citizens they may be of their own countries, will never be bound by a provincial nationalism

The history of science, since the war, has been largely of an effort to break down national barriers of mistrust or lack of understanding. In 1923, before an International Congress of Physiology in Edinburgh, various representative British physiologists were asked whether they approved—the French physiologists did not—of an invitation being issued to scientists in the late enemy countries. The general reply was that if the Germans were not to be invited they themselves did not propose to attend. The Germans came, and friendly relations were opened up again between physiologists: earlier than between almost any other groups on the two sides The political difficulties in other departments of knowledge have varied. Where, as in chemistry, competitive industrial or military application interfered, progress was relatively slow: in astronomy and physics it was rapid. This, however, is not the sole criterion, for physiology also deals with rather practical affairs: in physiology there happens to be a very friendly international spirit, bred partly by the congresses which Michael Foster founded in 1889. It is quite certain in any case that science can not progress properly except by the fullest internationalism. Accepting freedom of thought and research as the first postulate, the second is that knowledge, however and wherever won, should be freely available for the use of all Up to the beginning of the present year one lived in hopes that reason was being restored

Disillusion, however, has been brought to many by the events of the last nine months. No country has excelled Germany in its contribution to science in the last hundred years, no universities were traditionally freer and more liberal than the German. One felt that the intellectual cooperation of Germany was a necessity in setting science on an international basis I had intended, in this lecture, to urge an ever closer cooperation Germany, however, has lately rendered such intellectual cooperation impossible by offending the first and most fundamental rule, that providing freedom of thought and research. Such disasters have happened before in history, but one felt that the world had outgrown them. It seemed impossible, in a great and highly civilized country, that reasons of race, creed or opinion, any more than the color of a man's hair, could lead to the drastic elimination of a large number of the most eminent scientists and scholars, many of them men of the highest standing, good citizens, good human beings. This, nevertheless, has happened: the rest of the world of learning is gasping and wondering what to do about it. Freedom itself is again at stake.

The facts are not in dispute. I speak with some knowledge, having a personal acquaintance with, and having recently seen, many of the victims of the Aryan myth. Apart from thousands of professional men, lawyers, doctors, teachers, who have been prevented from following their profession; apart from tens of thousands of tradesmen and workers whose means of livelihood have been re-

moved, apart from 100,000 in concentration camps, often for no cause beyond independence of thought or speech, something over 1,000 scholars and scientists have been dismissed, among them some of the most eminent in Germany. These have committed no fault. Many of them are patriotic citizens who fought in the German armies in the war. One of them I know escaped from the French and went on fighting. One of them had a great-grandfather who fought in Blücher's army in the Waterloo campaign Many of them are of families which have been in Germany for centuries: not all of them are even partly Jews. It is difficult to believe in progress, at least in decency and common sense, when this can happen almost in a night in a previously civilized state.

What can be done about it? The immediate answer is, of course, that suffering must be relieved and opportunities given for the continuance of their work to those who have been persecuted and deprived. A more important matter, however, is this—we must ensure that the same folly, the same fury, does not occur elsewhere. We can not take the freedom, so slowly and hardly won, as a birthright: we must see to it that neither race, nor opinion, nor religious belief, nor the advocacy of theories unpopular perhaps at the moment shall cause disinterested able men to be deprived of the means of carrying on their work, even in some cases of their means of living. Mankind must not allow its cynics to reflect, with Richet, that its generic name, *homo sapiens*, had better have been *homo stultissimus*.

It is a gloomy outlook, and I can see little hope at present except by the strenuous cooperation of intelligent people of good-will in the various countries. I trust I am neither highbrow nor pessimist, and I know that I have great confidence in the moral judgments of ordinary folk. I have, however, little faith in their intelligence. Two friends of mine, a gardener and a cook, most excellent people, plain, simple, kindly, honest, can be deceived so easily that one need pay no attention at all to their opinions. With all my regard for them as human beings I can have no faith in the dictatorship of any proletariat of which they are typical. Equally difficult, however, I find it to believe in the dictatorship either of undergraduates or of glorified Boy Scouts (much as I love and admire these in their proper place). Of one thing, however, one can be certain, that in a civilization tottering unsteadily on a foundation of applied science, it is necessary that people scientifically trained should take some part in affairs. That need not imply that Cabinet Ministers should be fellows of the Royal Society, but rather that all educated men should have some appreciation, by direct contact, with the methods and ideas of science It is perilous to disregard the scientific basis of modern civilization or its dependence on international cooperation Science and learning—for all I said earlier in my lecture of their independence—must realize that they exist, not only for their own sake, not only for what they can do for the material welfare of mankind, but perhaps chiefly for the fact that they alone seem to be truly international, to be capable of transcending national follies and absurdities.

I do not suppose we can do very much, and I can imagine that *homo sapiens* may ultimately destroy by his irreconcilable folly all he has built up. His idea of progress, powerful as it is at the moment, may be nothing but an extrapolation from a short portion of a curve. The pterodactyl's achievements in aviation did not prevent him from dying out: he had some fundamental unfitness—may it have been an emotional one?—which for all his progress put an end to his career upon earth. Mankind's amazing intellectual achievement in under-

standing and controlling the forces of nature may be neutralized by the domination of his intellect by his passions, by his emotional inability to realize, what must be obvious to his intellect alone, the demands of a common humanity. The complete inhibition of his higher intellectual centers by storms of emotion from below, associated with delusions of grandeur or persecution, if persisted in for generations, may render him, for all his progress, in fact because of it, as extinct as the pterodactyl

The outlook, however, is not everywhere so bad and I venture still to think of science and learning, particularly science, which in its experimental method has an absolute means of deciding between opinions, as being the strongest links between the intelligent people of the world. Not many Englishmen, unfortunately, know much about the United States of America. People—otherwise intelligent—who would regard almost as illiterate one who had no personal knowledge of France, Italy, Switzerland or Germany, appear to be proud of their freedom from the contaminating influence of a visit to the United States They speak as though gangsters, bootleggers, fundamentalists, kidnappers, and the uneducated, unabsorbed European masses of the great cities, were part of intelligent America. Fortunately, scientific people know otherwise: they have good reason to know that laborious scientific advances, on the one hand, or brilliant discoveries, on the other, are just as likely to be achieved there as elsewhere: and they have that close personal contact with the unassuming friendly people who make these contributions to knowledge, which ensures that the scientific community at least would regard as utterly hateful any serious difference between their countries. This friendly rivalry between Britain and the United States, this sense of cooperation, is a stronger link than many may imagine. We scientific people are often poor, and generally without much honor or position: it is bad perhaps for the State but good for ourselves that this should be so for social importance and intelligent honesty are not easy bedfellows; but in the end we exercise more influence than we know—for our fundamental faith is cooperation in the pursuit of an end outside and greater than ourselves.

Huxley, whom we honor to-day, had three sides to his life and character. Firstly, the scientific side, in which he showed almost unexampled precocity With little aid, by the time he was 25, he had placed himself in the front rank of scientific investigators. Secondly, the side of public service. from the age of 37 years onwards he served on no less than ten Royal Commissions: he was secretary and later president of the Royal Society: he was a member of the London School Board: he occupied many public positions. Thirdly, the crusading side, by virtue of which he engaged for many years, against all comers, in the defense of scientific method and of freedom of thought and research. Great as were his contributions to pure science and to the state in his first and second faculties, it is for his services to freedom of thought that he will be remembered best. In a day when academic freedom is being challenged once again in many parts of the world, when honest opinion is being stifled by force, when advertisement and propaganda offer prizes to those who will deny their scientific consciences, when intellectual leaders are being persecuted by physical, not merely by intellectual, violence, it is good that we should remember and honor one whose valor in controversy made his country, for half a century at least, safe for honestly held opinion.

We need not recount his controversies: he defended the scientific method against witless prejudice and entrenched author-

ity. It is sufficient to remember him as a fighter in a good cause and to reflect that no good cause is permanently won. It is very unlikely that we shall have further struggles between evolution and the churches, but there are plenty of forces at work in the world to-day to hinder research, to destroy free thought, to strike at the root of all opinion not congenial to authority. At the moment in England we are free. We rejoice in our freedom. We can not imagine it otherwise, in spite of all our young communists and fascists. A year ago Germany was free, and its intellectual life, in its universities and its academies, was still the admiration of the world Neither Russia nor Italy to-day can claim—their rulers indeed would probably disclaim—that honesty and intelligence are safeguards for unpopular opinion. Who knows where next the epidemic of mass-insanity may appear? A little slackness, a little lack of watchfulness indeed, and our freedom here or in North America, in France or in the countries of northern Europe may disappear in a fortnight Let us not deceive ourselves. Many of those who now deplore most bitterly the events in Germany, the 100,000 in the concentration camps, the persecution of Jews, the blind acceptance of authority, not so long ago were maintaining that in making war at least the Germans were not much worse than ourselves. I believe they were wrong then, as I hope and believe we shall avoid the epidemic now; but we shall avoid it, not by denying the existence of evident facts, not by resting on the victories of our fathers, but by watchfulness and readiness to make sacrifices, if needs be, in the cause of intellectual freedom.

SOCIAL STRATIFICATION IN A SMALL COMMUNITY[1]

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EVEN though in America, especially in the democratic Middle West, we stoutly deny the presence of social classes, they do actually exist there. This universal trait probably develops from man's desire to classify or pigeonhole individuals

In order to study social stratification in its simplest form, I chose a small Iowa community, which we shall call Shellstone. This community is homogenous in religion, race and nationality, hence these elements will not complicate the process of social grading. There are no factories, mines or other economic agencies which bring about the obvious social cleavage between labor and capital. In other words, Shellstone is a simple, agricultural community with a small trading center.

At first sight there does not appear to be a social stratification among the people. When informants are directly approached they inevitably reply, "There are no classes in Shellstone." The organized social activities cut across all class lines. In the cities one finds different classes attending different churches. Formerly this was partially true in Shellstone, where the old aristocracy largely belong to the Baptist church, and were further set off from the multitude by dress, economic status and refinement. During the course of the twentieth century the social structure of Shellstone has been leveled downward and class lines obscured.

Shellstone likes to pigeonhole individuals, however, and from this tendency develops a loose class system. Social position is largely determined by the function which one fulfils in the economic process, and the subjective evaluation placed upon that function by the community.

But the economic position of the individual is not the only factor in his classification. It is modified by the concept of permanency of occupation and stability of character. The individual who frequently changes occupations or employers is grouped with the lower classes, *regardless of his occupation at the time being.* Other results of this modifying element will be cited in the section on the social classes.

In describing the classes in Shellstone one must constantly guard against the erroneous idea that the individual's personality is overshadowed by the class label. The classes described are but a rough description or classification of groups of individuals. Each of these classes have nearly as many subclasses as there are individuals. In a well-developed class or caste system an individual is first a member of a class, and then, possibly, an individual. In Shellstone, one is first an individual, and then, because of his personality, a member of a class. As a result of this personal evaluation, even with so functional a basis of classification as has been given here, there are individuals who do not fit into the classification or who do not move in the class in which we would ordinarily consider them as belonging.

In Shellstone, the banker stands at the top of the economic and social hierarchy. Economically he is the lord of the community. He knows every one by name and financial standing. In time of

[1] The data for this are taken from "An Ethnological Study of a Small Middle West Community," an unpublished manuscript.

financial stress or crisis he is appealed to for aid. The farmers ask his advice about renting a different farm, holding or selling their hogs, buying more land or making improvements on their farms. The merchants and townspeople seek his advice concerning new ventures and are backed by him financially. In case of disputes, legal or personal, he is usually appealed to and his decision is accepted by both parties In questions involving points of law, his advice is sought. If a land deal is being put through, it is usually closed in the bank in the presence of the banker, the latter drawing up the agreement. If an out-of-town man owes some one some money, the banker writes him a letter which usually collects.

All this service is given for the asking. The bank receives no revenue from personal service. Even bank drafts cost nothing in Shellstone. This free service and advice is undoubtedly the explanation for the fact that while Shellstone has dwindled in significance as a trade and social center the banking institution enjoys as much prestige as ever before. Such human understanding and service is the secret of the popularity of benevolent despots. The authority of Shellstone's despot remains almost unchallenged by rivals or the people themselves.

The prestige of the banking families does not rest alone on their occupation. Their families were among the oldest settlers in the town and at once took an active part in the economic development of the town by operating one of the first stores. Both generations have proven themselves to be stable, balanced and dependable citizens. Their position was challenged unsuccessfully when a group of disgruntled citizens organized "The Farmers' State Bank." A very able man was put in charge, but he never gained the prestige granted to the other group. The new state bank closed its doors in 1925, and the private bank once more enjoys the patronage and prestige of the entire community. The failure of the state bank has served to augment the respect and confidence of the people for the old firm, which continues business unhampered by either state or national control.

The business associates of the banker enjoy a prestige next to that of Barter, the president, whether they may be working in the bank as cashier, assistant cashier, bookkeeper or janitor. Incidentally, they are not relatives of the banker, but young men who have been reared in the community and employed in the bank after graduation from high school. They rank high in the functional classification of Shellstone. The position not only brings them in close contact with the real power in the community, but it is a symbol of the recognition of merit. To answer, "He works in the bank," is the equivalent of saying, "He is a good boy; he is honest; he works hard; he is the most intelligent young man in his age group and he is so good that his talents have been recognized by Barter."

Next in the hierarchy are what Shellstone calls "business men." This includes all men who own or operate some kind of a business establishment, regardless of whether he sells material commodities or his own skilled labor. The important item is to have a regular place of business. The blacksmith and barber are considered as much business men as are the merchants. In this class of business men is included the owners and operators of the following businesses:

1 Produce house	1 Photo gallery
1 Mill	1 Electric shop
1 Post-office	1 Harness and shoe store
1 Shoe store	2 Hardware stores
1 Barber shop	1 Dry goods store
3 Grocery stores	1 Newspaper office
1 Cafe	2 Garages
1 Furniture and undertaking	1 Gas station
1 Blacksmith and implement shop	

The above group includes thirty-six households. In the days before the trade decline it would probably have included as many more, for most clerks were considered to be in the business group, due to the relative permanency of their connection with the business institution. Shellstone places service and permanency of occupation on a par with business ownership. As a rule, the employee who works in one store for a long period of time enjoys the same social position and respect as his employer, while the individual, whether entrepeneur or employee, who changes business or occupation frequently is denied the respect and prestige granted the former.

The above list of the business class does not include the operators or owners of the following businesses:

East Side grocery	Grocery and dry goods store
Meat market	One produce house
Drug store	
Garden café	

All except the last have been omitted because they are comparative newcomers. In Shellstone, social recognition as a part of the community is not gained through the purchase of a business, but must be earned through a rather prolonged residence in the community. The above-mentioned people are, as yet, considered outsiders.

The operator of the produce house does not enjoy recognition as a member of the business class because, although he has been reared in Shellstone, he has changed occupations frequently, and for the greater part of his life was among the casual laborers with whom he is still classed.

The doctor and dentist are included in the business group. The former has been in Shellstone for nearly twenty years, but it is only recently that he has been admitted to the business group. The dentist was reared in the community and has practised dentistry here for thirty years. The agent for one of the railroads at Shellstone for nearly fifty years was classified with the business men.

The next class is landowners, including either active or retired farmers. Like the business men, they are subject to the same general rules of permanency and stability. This group is very close to the business group in prestige. In fact, the retired farmers and the old members of the business group freely mingle together socially. Formerly the partial isolation of the farmer kept the groups from becoming intimate, but since this barrier has been broken down many members of the two groups associate at the intimate level of social participation.

The farm renters, as a group, rank somewhat below the landowners, although here again the factor of permanency and ability complicates the picture. The individual who lives on the same rented farm for many years and is a successful farmer enjoys the same social recognition as the landowner. On the other hand, the poor farmer who moves from one farm to another at frequent intervals ranks with the occasional or casual laborer whom the writer shall next consider.

In any civilized community of people, most individuals need, from time to time, additional help in planting the garden, raking the yard, beating rugs, washing windows and so forth. On the farm there are times of increased activity arising from the necessity for the completion of certain work, such as planting and harvesting at a fairly definite time. During these periods, the farmers hire extra help, usually by the day. In response to this need of the community has arisen one of the most distinct classes in the social and economic structure of Shellstone. I shall call this group the occasional laborers. They are the odd job men, "Jacks of all trades and master of none." Economically they are as indispensable as any other group, but socially they do not mingle

with the other classes. As has been pointed out before, the people of Shellstone highly value permanency of employment, stability and industry. The occasional laborers lack this virtuous trinity. The very nature of their economic instability probably tends to develop inconstancy of character, or what the community designates as "laziness." The cause and effect relationship of these traits of character is believed by the virtuous to be the opposite of what has been suggested above, that is, laziness and questionable character are inborn traits which determine one's choice in the economic process. The validity of this theory is of little importance. As long as the people believe it is true, they react to the occasional worker and his family "as if" it were true.

Among the occasional laborers are a number of individuals inclined toward stealing. This is not a new group, but has been in existence since the beginning of the town They represent the very bottom of the occasional laboring class. They work the least, live in the poorest houses, have the least amount of money and the most children, are shiftless and often dependent upon the community for support. Their thefts are usually articles of little value, such as tools, garden truck, automobile tires and accessories. Formerly, a few chickens were stolen, but due to the increased opposition of the community to chicken thieves, most of them do not take that risk.

The community knows these petty thieves, but takes no action against them as an organized community. The individuals attempt to guard their property by means of padlocks and personal vigilance. Occasionally an item of warning and bluff appears in *The News* similar to the following:

Those chaps who are stealing Elder Brasted's wood at night had better look out. There are two revolvers at his house loaded to the brim that will explode some night and blow them where the woodbine twineth.

If one of these individuals is caught in the act of thieving, he hurries home and the owner of the property is satisfied that he has been able to retain his goods.

The bankers, and their associates, the business class and successful farmers, the poorer farmers, mostly farm tenants, and the occasional laborers are the social classes based upon the economic function plus the stability and permanency of the individuals. The lines of demarcation are vague and elusive. The upper and lower limits of the classes shade into each other. They are not institutionalized and the populace do not recognize the classes as such. Neither inheritance nor wealth are important items in determining the class to which one belongs.

The classes include only adults. Children are free from class distinction. The children of the business men, occasional laborers, farmers and bankers, play together on equal terms except when the undesirable traits of the parent are actually present in the children. Then those naughty children are tabooed except to children whose parents do not object to such behavior.

Shellstone cherishes the American myth of equality of opportunity for all and does all within her power to make it a reality. The boy or girl of worthless parents is aided and encouraged to make good. Shellstone has few opportunities to offer them as adults, but every individual will aid them during their youth in getting an education. All a young person needs to do to receive such aid and encouragement from the community is to work hard, start a savings account and be dependable. Several boys of this type have made good out in the outer world, and they are the pride of the community.

Another group of individuals, mostly unmarried men, must be described. This group is outside of the economic, functional classification. For want of a bet-

ter name, they shall be referred to as "men about town." Not even in times of labor shortage do they work. Their sustenance is from a source other than their labor, usually a small inheritance. They are honest and upright citizens, who take a far greater interest in local and national politics and problems than do their more industrious friends. As individuals (no one would think of them as a group), they attach themselves to various business houses or institutions. One of them "hangs around" one of the hardware stores, where, upon occasion, he may help load a stove into the truck. Such services are not given for pay, but in the same spirit that a farmer would "lend a hand" if he were present at such a time of need He is also a sort of henchman of the business. If something new comes in, Shady Mack advertises it as much as the newspaper and brings his friends in to look at it, while he explains its intricacies and good points. Of course he never sells anything. If the competing hardware merchant has a different brand of some commodity, Shady is ready and willing to explain the superiority of the brand handled by the store at which he "hangs out" and the trouble given by the competitor's brand. Such a publicity man is of considerable value to a merchant.

Another of the men about town is a college graduate of about forty-five years of age. His work is caring for and representing the Masonic Lodge, of which he is one of the leading members Not having anything else to do, he acts as caretaker of the lodge rooms, plans and directs the activities of the lodge on the occasion of the death of one of the members, visits the sick fraternal brothers and peps up the more stolid and less enthusiastic members of the order.

These men serve a public function. They have both the time and inclination to read a great deal, and are rightly considered the best generally read men in the community. Politically they serve as relay stations for the Republican propaganda. They are also informants as to the proper treatment of all plant and animal diseases, the proper time to plant and harvest the various crops, and the means and ways of destroying obnoxious weeds. Their knowledge is an amusing combination of science, magic and superstition. A detailed study of their beliefs would reveal both the progress of science and the tenacity of superstition among the ordinary populace of the American Middle West.

This group is also the exchange for news and gossip. Through them the news from one end of the community reaches the opposite end. They know all the farmers who come to town and get the news and crop reports concerning that portion of the community from which they come. From them the farmers learn the crop conditions and events of the entire area of the community.

All these functions are carried on in an informal, friendly and gossipy manner. The high regard which they enjoy, in spite of the fact that "they toil not, neither do they spin," from a community in which industry is considered one of the cardinal virtues is perhaps an unconscious recognition of their service in the social process.

The question arises as to why the occasional laborers, who spend much of their time in the same way as the "men about town," do not enjoy an equal prestige. At first thought one might believe the discrepancy to be due the wealth of these men Such can not be the solution, for, excepting one case, the "independent means" is an extremely meager one, leaving, after taxes have been deducted, probably four hundred, certainly not over five hundred dollars per annum for living expenses.

The families from which they come were of only average standing and in one case unknown to the villagers. Shellstone does not as a rule grant recog-

nition of an individual because of the worth of his family. Both salvation and social standing is believed to be an individual matter. From the standpoint of morality and honesty, the men about town are not better than many of the occasional laborers whom they outrank.

They do differ from the occasional laborer, however, in permanency and predictability. The natives of Shellstone like to know not only what a man is doing to-day, but what he will be doing to-morrow, next week and next year, and where he will be doing it. The occasional laborer's activity and whereabouts can not be so predicted. But barring death or accident, even the child playing in the street can tell you what any one of the men about town are doing ["nothing"] and where he is doing it.

The married women of the community enjoy the social standing earned by their husband's function in the economic process. Most of the girls who remain in the community marry shortly after graduation from high school. During the period between graduation and marriage the girls are more or less outside of the social classification, but those who "get out and work" are more highly regarded than those who remain at home.

After graduation from school the boys who remain in the community begin to win their position in the social structure of the community. They are closely watched at this period. The boys who work away from home, like the girls, enjoy more prestige than those who remain with their parents. And those who secure positions away from the community outrank any who remain at home.

The local teachers and ministers are individuals who reside in the community but are not of it. They are considered outsiders and treated as such. The teachers are forced by their contracts to participate in the religious activities, and they must help the children prepare entertainments for the amusement of the community. Their contract also requires them to remain in the community a certain proportion of the week-ends. But those periods are indeed dreary times for the teachers. They are rarely invited into any homes in the community. And they must clique together for comradeship. Their every movement is watched by the people, who are ever ready to criticize their conduct. Their tenure of office is short, for, regardless of the quality of their work, the people desire changes.

The position of the minister's families is similar to that of the teachers The men of the community do not care for the comradeship of preachers, whom they look upon as effeminate creatures who call upon the women and attend the Ladies' Aid. The conduct of the ministers and their families is subject to the same strict observation and sharp criticism as that of the teachers. Their tenure is likewise limited. The Methodist ministers are, of course, subject to the call of the Conference, which apparently recognizes the desire of the small community for frequent pastoral changes. The Baptist ministers frequently make the error of remaining too long and depart ignominiously as a result of their folly, leaving each time in their wake a church weakened and split from internal dissension.

Shellstone is a closed community and mainly self-perpetuating. It is the source of an overflow into the cities, but draws few new members from other parts, except on the fringes of the farming area. Those young people who remain within the community also marry there as a rule. Most families are distantly related, although seldom has actual intermarriage of relative occurred.

Occasionally, however, a new family moves into town. It may be that of a new depot agent, a manager of a chain store, a physician, or, now and then, some one attempting to establish a business or trade. The process by which

they are admitted to membership in the community is slow and somewhat dependent on the recognition enjoyed by his predecessor. This is evident in the reaction to the depot agents of the two railroad lines. The former agent on the Rock Island line was from Shellstone and remained in the position for fifty years, enjoying high social recognition in the community. His successor, although entirely unknown to the community, was quickly admitted to the business class. On the other hand, the Great Western line has made frequent changes about every five years, and the agents representing it have never enjoyed the full social recognition granted in two years to the last Rock Island representative.

It is practically impossible for a strange merchant to gain either social recognition or patronage. One local merchant, owning one of the most prosperous businesses in town, sold out to a stranger in 1917. His trade consisted only of a few of the curious and he was forced to give up the store. Several others followed in rapid succession, but none were able to gain a profitable trade. In 1931 the oldest firm in town, established for more than fifty years, was bought out by two very efficient business men from a distant town, where they had owned one of the most modern stores to be found in any small town Their ability as merchants can not be questioned. Yet they have been unable to build up a trade, even when the prices on their goods are well under those of the other stores. The writer asked several people what they thought of the new store. The answers were, "I haven't been inside of it since Newcomb sold out."

A chain concern bought out a flourishing lumber business and sent manager after manager to the town in their attempt to bring the business up to normal, but without success. The people rationalized the withdrawal of their patronage on the basis that the chain concern took their money out of the community. That such was not the reason was proved by the fact that when the concern finally employed the former owner to conduct the business for them their trade immediately jumped up to what it had been formerly.

If Shellstone were isolated from the rest of the world, we would believe their attitude due to suspicion of strangers. Yet these same people who avoid local stores under new management go, on the average of once a week, to a small city, where they have many business contacts with strangers. It can not be that, although they do not fear to be among strangers, they yet fear strangers in their midst.

We shall now turn to an examination of cases in which newcomers have been admitted to the community. The most frequent source of influx has been young men who come to the community and "hire out"[2] to some local man either on a farm or in some business such as drayage. There are many cases of this kind in which the immigrant works with his employer and is sponsored by him, so to speak, and finally becomes a recognized member of the community.

One merchant, when he bought out a business, retained all the old clerks and remained in the background himself. The business continued without any dissensions, although he and his family were not admitted until several years later. Recognition as a member of the group was gained through one of the lodges to which he and his wife both belonged and which they attended regularly, although they were not cordially accepted. After more than two years one of the leading business families became friendly with them and the two families "went around together." As soon as they were thus sponsored, admittance into the community was granted.

Another important item in business success for a newcomer is patronage and

[2] This was of frequent occurrence until within the last twenty years, but is now rare.

recognition by the dominant families, who, as mentioned elsewhere, are the bankers. Newcomers who have been admitted have told the writer that without the acceptance of that group it is practically impossible to make a living from a business in the town. Another family important to the newcomers is the Wests, who are one of the most dominant families in the Methodist Church. Mrs. West is one of the few who will take it upon herself to get acquainted with new people and—still more important—if she likes them, their praises will be sounded throughout the community Of course, if she does not like them her influence is equally strong in the other direction.

Admittance to the community through the farming group is not so difficult to gain. The very nature of farming requires an exchange of work among the men, and as the newcomer is usually a renter he is sponsored by his landlord, who is usually a retired farmer living in town

Formerly the women of the town or neighborhood called on the newcomers at an early date after they were settled Such a practise has for the most part been dropped. Now the newcomers must take the aggressive part. After they have met people who seem agreeable, or with whom they wish to become more friendly, they must plan an auto party or invite them over for an evening. It is only by becoming intimate with an accepted family and thus gaining a sponsor that they can hope to gain recognition And the newcomer must play the aggressive part or remain at home friendless in a strange community. This change of folkways may be due to the increased importance of the acquaintance groups as opposed to the neighborhood group.

Formerly the agricultural area was divided into neighborhoods, that is, a small area in which the people were closely associated, socially. The most of an individual's close friends lived within this area. It was the unit of many social activities. Now the neighborhood exists as an economic unit, but not as a social unit.

In place of the neighborhood group there has developed the congeniality group Geography no longer determines one's friends and acquaintances, but has given way to the choice of the individuals As a result the social groups in Shellstone are of a more homogenous character now than formerly.

CONSERVATION OF GAME OR OF WILD LIFE—WHICH?

By W. L. McATEE

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To many, game *is* wild life or at least the only part of it worthy of attention. To others, game is an artificial classification for a limited number of species which are no more interesting nor more worthy of preservation than others To the present observer and writer, endeavoring to be fair, it seems that the view of the latter group is the more nearly correct. If we tabulate the number of kinds of animals reckoned as game or non-game, we find that 88 species or 14.66 per cent of our fresh-water fishes, 69 or 8.50 per cent. of our birds, and 82[1] or 12.24 per cent. of our mammals are currently classed as game, while no amphibians or reptiles seem to be so regarded. If we take the percentage of the total number (239) of game species among those of all (2,368) of the five groups, we find it to be just about 10 (10.09). What of the remaining 90 per cent.? That 90 per cent, from the standpoint of general wild life conservation, is certainly entitled to consideration.

Upon what basis, it is fair to inquire, does game rate the inordinate share of attention it receives? For its food value? The answer is "Assuredly not," and for several reasons. For one, every piece of game consumed costs on the average many times what an equivalent in food value could be purchased for in the market. For another, game, except to settlers or travelers in remote districts, is no longer an indispensable part of the food supply. It could not be, indeed, for our population could eat all of the game in the country, if available, in a day—almost, we were on the point of saying, at a meal. The essential basis of civilization is reproduction of food supplies, and we are so far civilized as to be cursed all the while with overproduction. Except under pioneer conditions now all but vanished, game is not necessary for food, and its pursuit therefore comes under the heading of non-essential activities.

The recreational value of the pursuit of game admittedly is large, and is the greatest public value now dependent on game. But is it indispensable? Ask the golfer, or any other out-of-doors enthusiast whose recreation does not involve the hunting and killing of wild life The chase may be, nay is, defended on a variety of grounds, but in fairness even its strongest proponents must admit that under present conditions it falls largely in the luxury class. All this is not necessarily to decry hunting, but to lead the way to a conclusion the writer deems inevitable, namely, that hunting being a luxury, there is no validity in arguments for sweeping aside everything that interferes with it.

That such demand exists is obvious but even so some readers may wish to scan the evidence with their own eyes. It is given in the case of land game by the following quotation from a published report on a leading state game department: "The Conservation Department is entirely awake to the vital importance of unstinting warfare upon 'vermin,' if a plentiful supply of game and other useful wild life is to continue. . . . Every sportsman, every farmer,

[1] Only 18 groups or "species" of bears are counted.

and everybody else who believes in the conservation of useful birds and animals must enlist in the campaign and do his share." The same organization has the following to say regarding the enemies of game fishes: "The tremendous drain on game fish, their rapid depletion in our lakes and streams, and the urgent demand that we conserve and replenish these denizens of our waterways necessitates the most thorough elimination of all agencies which are detrimental to the welfare of game fish."

Let us consider what constitutes the groups of wild life dubbed "vermin" by those interested primarily in game. The tendency is to condemn these out-of-hand and to wage war upon them at every opportunity. But what are "vermin"? They are not animals that have no value of their own and in which no one is interested. On the contrary the largest single group of creatures that game protagonists regard as "vermin" are the fur-bearing mammals. These animals are a source of revenue to trappers, and to the fur industry in all of its branches and they are protected by law almost to as great an extent as are game animals themselves. This protection often is conveniently forgotten but there would seem no legitimate basis for prejudice against this group compared to game, as it has a value of its own and has won legal protection strictly on its merits.

Of the birds classed as "vermin" more than half of the species, including most of the fish-eating kinds condemned by anglers, are protected by federal law. This protection was not given without good reason: it was to guard the birds against extermination. Many of them were threatened by the plume trade, and some, as mergansers, are part of the class of migratory wild fowl upon which it was necessary to restrict the open season. From the standpoint of general wild life conservation, the protection of these species against extermination is a far more valuable and desirable thing than is maintenance of a killable surplus of game species.

The "vermin" species among amphibians and reptiles are more generally regarded as of little worth but some of them as the alligators and snapping turtles have commercial value. The main value of the spawn-eating and other "vermin" fishes is as a food supply for the game and commercial fishes.

The numbers of game and commercial species in the various orders of animals, compared to those regarded as "vermin" are shown in the accompanying tabulation.

Wild life group	Approximate total number of species	Game and commercial species	Per cent	Reckoned by some as vermin	Per cent
Fishes (fresh-water)	600	132	22.00	378	63.00
Amphibians	138	3	2.17	3	2.17
Reptiles	149	24[2]	16.10	60[2]	40.26
Birds	811	69	8.50	142[3]	17.51
Mammals	670	198[4]	29.55	189[4]	28.20
Average			15.66		30.23

[2] 5 species (including the crocodile, alligator, and snapping turtles) are the same in each group.

[3] 76 of these species are protected by federal law.

[4] 116 species (fur-bearers) are the same in each group; many of these animals are protected by state laws.

ECONOMIC CLASSIFICATION OF WILD LIFE OF THE UNITED STATES

FRESH-WATER FISHES

Species of game or commercial value: Spoonbill, 1; sturgeons, 7; herrings, 2; shads, 2; whitefishes, 21; salmons, 6; trouts, 32; graylings, 2; smelts, 3; eel, 1; buffalo-fishes, 3; redhorse, 1; carp, 1; fall fish, 1; squaw-fish, 1; catfishes, 10; pikes, 5; sunfishes, 22; crappies, 2; basses, 2; perches, 2; striped basses, 2; white perches, 2; sheepshead, 1.

Species often classed as vermin: Lampreys, 9; gars, 3; dogfish, 1; suckers, 43; minnows, 227; madtoms, 10; sticklebacks, 6; darters, 65; sculpins, 13; ling, 1.

AMPHIBIANS

Species of game or commercial value. Frogs, 3.

Species often classed as vermin Mud-puppies, 2; hellbender, 1

REPTILES

Species of game or commercial value: Crocodile, 1; alligator, 1, chuck-wallas, 6, snapping turtles, 3, terrapins, 2, green turtles, 2, hawk-bill turtles, 2; loggerhead turtles, 3, soft-shell turtles, 4.

Species often classed as vermin· Gila monster, 1, racers, 10; chicken-snakes, 10, water-snakes, 12; coral snakes, 2; rattlesnakes and allies, 20, (sometimes the alligator, crocodile, and snapping turtle), 5

BIRDS[5]

Species of game value: Geese, 8; ducks, 25; grouse, 12; partridge, 1; quail, 6; pheasant, 1, turkey, 1; limpkin, 1; rails, 7; gallinules, 2; coot, 1; jacksnipe, 1; woodcock, 1, doves, 2

Species often classed as vermin Loons, 4, grebes, 5; pelicans, 2; cormorants, 5, water turkey, 1; herons, bitterns, etc., 12; mergansers, 3, hawks, 28; jaegers and skuas, 4, gulls, 20, terns, 14; skimmer, 1, auk, 1; murres, 2; guillemots, 2; puffins, 3; road-runner, 1, owls, 17, kingfishers, 2, jays, 6; magpies, 2, crows and ravens, 4; dipper, 1; shrikes, 2

MAMMALS

Species of game or commercial value: Bears, 18; squirrels, 7; rabbits and hares, 19; peccary, 1; elk, 3; deer, 8; moose, 2; caribou, 13; antelope, 1; bison, 1; muskox, 1, sheep, 6; goats, 2; (116 species of fur-bearing animals which may also be reckoned here), 116.

Species often classed as vermin: Opossums, 2; raccoons, 3; civet cat, 1; martens, 7; weasels, minks, etc., 23; wolverines, 7; otters, 3, skunks, 20; badger, 1; foxes (some game), 17; wolves, and coyotes, 15, bobcats, lynxes and mountain lions, 11; sea-lions, 2; seals, 6; spermophiles, 40; chipmunks, 16; red squirrels, 3; cotton rat, 1; wood rats, 10; armadillo, 1.

In every case the number regarded by some as "vermin" is about equal to or exceeds that of game and commercial species, which brings up the question at once as to the advisability of sacrificing the former for the benefit of the latter. The general conservationist certainly will oppose the proposal and again he will have logic on his side, certainly so far as game and opposed groups are concerned, as they are on about the same footing so far as essential value to the country is concerned; under these circumstances it is natural to favor the groups in proportion to their numbers.

With respect to the "commercial" species, it must be admitted that they are not commercial in the sense that poultry and cattle are, for the market product is merely drawn from a public stock with the production of which the marketer has had little or nothing to do. In such a case, the fish supply for instance, if the public by statute protects fish-eating birds, that is merely another way of saying that the public wishes to devote to the upkeep of these birds whatever quantity of fishes is required. The harvest, like all harvests of natural products, should be from a surplus, and in the case outlined the surplus does not begin until the needs of community-protected fish-eaters are satisfied. Parenthetically it may be noted that in reality all of this is not nearly as bad as it sounds, since the prey of fish-eating species is largely derived from the non-commercial and non-game fishes, that is from groups, some of which are usually named in the "vermin" class This follows inevitably from the general law of predation being in proportion to population—since the non-commercial and non-game fishes under nearly all circumstances far surpass in numbers the more valuable kinds.

Exceptional cases are at fish hatcheries and fish ponds where valuable species are being propagated, and due provision has been made by the federal government for control in such places of the destructive activities of birds protected

[5] Stragglers and permanently protected species have been excluded.

by national law. Similar exceptional cases involving game species are game farms and game refuges, where the primary purpose, fostered by definite efforts and expenditures, is game production.

These principles, however, cannot legitimately be extended to "vermin" control at large and it is efforts to do this that so justifiably arouse the protests of general conservationists The country at large is not now and never will be comparable to a game farm and efforts to apply a single phase of game farming —"vermin" control, when all of the others are lacking, is indefensible and contrary to sound public policy—policy that should consider equally the interests of all classes and of all things.

Not to exceed 10 per cent of the wild life species of the country are game and only about 15 per cent. have either game or commercial value. Many of the species of commercial value are rated as "vermin" by game breeders and together with other species put in this category by hunters and fishermen make up about 30 per cent. of the total number of our forms of wild life. The remaining "greater half" presumably are neutral from the "vermin" point of view. But what of the 30, shall they be considered fair marks for warfare in behalf of the 15? Since they include all of the valuable fur-bearers of the country as well as other species having some commercial value, many protected by law, besides numerous interesting species that for good and sufficient reason have been given strict legal protection, the answer from the legal standpoint alone is a decided negative. Campaigns against "vermin" cannot be carried on without grave risk of law violation.

Other forms of wild life often referred to as "vermin" include birds that are by no means chiefly injurious in their feeding habits, as well as reptiles and mammals that do little harm. All are interesting species, the extermination of no one of which is desirable.

Conservation of wild life is a broad term and it applies to all species. Half of our wild life should not be forgotten, nor should three-tenths be sacrificed for the benefit of one-tenth Attempts to conserve in the wild one group at the expense of another is seldom justified. Those favoring far-reaching "vermin" control should be able to see that the general public, so far as it is interested at all, is interested in wild life in general, not especially in game, also that there is a class of the population, probably as numerous as their own, that is definitely interested in general conservation as opposed to game conservation.

To put it concretely, when anglers wish to shoot up a colony of great blue herons which they consider detrimental to their interests, they should consider the following facts. This heron is a large, ornamental and interesting bird, the mere seeing of which makes a red-letter day for a nature lover, it is a migratory species which thus shows itself to naturalists over a wide range. If destruction of the birds has the effect hoped for, it will at most mean only a few more trout to be shared among all the anglers of the region. The catching of these trout is not a necessity to the anglers, it only affords a thrill and no greater one than the nature lover experiences from observing the herons. There is no argument for sacrificing the pleasure of the general conservationist to that of the fisherman. In addition, the fact should be very seriously considered that the heron does not feed exclusively or even largely on trout. It eats insects, mice, gophers and many other creatures, and from the very nature of things catches as a rule far more coarse than game fishes, and these are

those very enemy and competitor fishes that are known to be the greatest check on stream restocking operations. At the same time these fishes in their younger stages are an important source of food for the game species. In addition to all else that has been said, anglers should remember that the number of fishes cannot be increased indefinitely. A stream or lake has only a certain fish-carrying capacity, and if an excessive number of fishes are present, they will be of smaller size.

Interrelations of forms of wild life are highly complex, and building up the sport of trout fishing is not so simple a thing as implied by the slogan "Come on, boys, let's shoot up the herons." A typical feature in such a case also is the law violation involved, as great blue herons are protected by federal law. This is merely an illustrative instance; in all others as well difficulties will be found, and similar entanglements of life relationships, like confusions of interests.

Conservation of game alone cannot be successfully achieved by hastily adopted and ill-considered methods, and conservation of wild life in general, which is the only sound public policy, should be based on the most complete obtainable knowledge, on justice, and consideration, giving due weight to the interests of all people and to the welfare of all nature.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

HOW ANIMALS SPEND THE WINTER

By AUSTIN H. CLARK
U. S. NATIONAL MUSEUM

WINTER out-of-doors, when compared with summer, seems almost a dead season. Most of the trees are leafless, and the grasses and low plants are dead, or at least seem to be In the north the ponds and lakes and streams are blanketed with ice more or less completely, and the ground is frozen for some distance down

Most of our familiar friends among the birds are missing, but in compensation for their loss we see, chiefly along the coast and about the open waters of the larger streams and lakes, various other kinds that are not with us in the summer. Nearly all the various sorts of field-mice have completely disappeared. The bears have vanished from the wilder woods. Squirrels are seen but rarely, and only on warm, bright and sunny days. Snakes, turtles, frogs and toads are merely memories. And there are no flies or wasps or bees or butterflies or other sorts of insects.

The world seems almost dead. And yet we know that with the advent of the warm spring days it will come to life again So it is clear that it is not really dead, but merely sleeping; that somewhere and in some fashion most of the familiar life of summer is resting quietly, but is prepared and ready to awaken and to become active with the coming of the spring.

Some creatures are always active. For instance, all the birds are just as lively and alert in winter as they are in summer. They live the same life throughout the year With us the crows and jays and various other kinds of common birds are just as familiar features of the winter landscape as they are of the green woods and fields of summer But in the case of very many birds the coming of the winter reduces their food supply, or even altogether cuts it off As an example, the disappearance of the insects cuts off the food supply of the insect-eating birds, and the freezing over of the ponds and lakes and streams prevents the ducks and geese and herons and other water- and shore-feeding birds from getting the food they need.

So in order to live during the winter months most of the northern birds are forced to leave their homes and to move southward into regions where the insect life has not been chilled into inactivity, and where the waters are still open.

Some of our birds, as the common robin, go only a short distance southward, into the southern states, where the winter is less severe than it is in their northern homes Others, like the swallows and the warblers, go further, to Central and northern South America and the West Indies. In the West Indies in the winter, in the heat and brilliant sunlight of the Tropics and among the palms, bananas, mangoes, limes, nutmegs, bread-fruit, and many other equally unfamiliar plants, and along the white and glaring coral reefs, it is an interesting sight to see several of our familiar northern birds apparently just as happy and just as much at home as they are with us. For instance, our kingfisher is a well-known and common bird in the West Indies, and about the

bushy hillsides and the gardens of those islands our redstart is not at all uncommon. Along the mountain streams the spotted sandpiper runs about wagging his tail just as he does along the streams in Massachusetts or in Maine.

Birds are very interesting creatures. With nearly all of them sight is the most important sense They find their food and avoid their enemies by means of their unusually keen eyes A few, as most owls and night-flying birds in general, have wonderfully keen ears, but for the most part the eyes are the chief reliance of the birds. And so it naturally follows that the longer the day the longer the time in which any given bird can find its food and avoid its enemies. Night is a time of danger for most birds The darkness brings many dangers. So besides the question of securing food there is for birds the problem presented by the long winter nights Some birds, such as the golden plover and the Arctic tern, breed in the far north, at the time when the days are longest, or at least are very long, and the night is short, or there is no night at all These birds after the breeding season journey south and, passing through the Tropics, spend the winter in the southern portion of the southern hemisphere, where it is then summer and the days are long The Arctic tern has the longest migratory flight of any bird. In the summer it is found about the Arctic ice, while in the winter it is equally at home about the Antarctic ice, ten thousand miles away This bird, the golden plover and some other shore birds have two summers every year. The shortest days they know are those they see when passing through the Tropics, where the days and nights are always equal

The birds with their power of flight are able to move about over great distances and to avoid the northern winter by simply moving south. Among the mammals such extended journeys are only in rare cases possible. Some of the bats go south in winter, and in the early days the buffalo in the east withdrew in winter from the northern portion of its range into the southern states.

But most of the mammals stay more or less at home in winter, though they may wander widely in their search for food Many of them, like the bears, the woodchucks, most of the wild mice, the common squirrels and some of the bats, when the autumn comes find a suitable place, or make one, and therein pass the winter in that long sleep called hibernation. During this period of hibernation the body temperature is lowered so that they exist with the least possible expenditure of energy.

In the same way the snakes and the box turtle find an appropriate place or burrow in the ground and sleep away the winter. The pond turtles and the frogs burrow in the mud in the shallow water along the shores of ponds or lakes or streams and spend the winter under a protective covering of ice

The fishes for the most part stay where they are or move into deeper water. But some, like the northern trout, if they can do so, go into the salt marshes or the sea. In the far north, where the bogs and ponds freeze solid, certain of the fishes are firmly frozen in the ice where they remain immovable until the thaws of spring release them. During the short summer they are active, but for most of the year they are asleep in their solid icy prison.

The backboned animals all are large, or at least they are larger than the insects But insects, small and delicate as they are, survive the winter quite as well as any of the backboned animals. Insects pass the winter in every conceivable way, and in every conceivable condition. Many of them, as some of our butterflies, wasps, bees, flies and others, live through the winter in the adult stage, hidden away in some snug retreat. A few warm days in winter often serve to bring them out, and they fly around

until the returning cold puts them to sleep again. Very many butterflies and moths spend the winter as chrysalids, which among the moths usually are enclosed in a silk cocoon, but which among the butterflies usually are uncovered. In most cases the caterpillars transform to chrysalids toward the end of summer or in the early autumn, and the butterflies or moths emerge in spring One of our smaller butterflies, a very pretty one called the orange-tip, flies in March and April, lays its eggs and dies. The caterpillars that issue from the eggs feed until toward the end of May, then turn to chrysalids These chrysalids remain inert, fastened to the trunks of trees all through the heat of summer and the following cold of winter, until in early spring the butterflies emerge. Two thirds of the entire life of this delicate little creature is spent asleep in the chrysalis.

Some other butterflies spend the winter as full-grown caterpillars hidden away in a loose cocoon. In the first warm days of spring these caterpillars transform to chrysalids from which in a few days come the butterflies Still other butterflies live through the winter as caterpillars partly grown, which in the spring complete their growth and then transform to adults. Most of those butterflies called fritillaries, in color golden brown with silver spots on the under surface of the hinder wings, lay their eggs in summer. The little caterpillars that issue from these eggs lie quietly on the ground and will not eat until the following spring. For six or even seven months, through the heat of the late summer and the cold of winter, they are completely passive, waiting for the proper time to begin to eat. A few butterflies and many different moths spend the winter in the eggs which are laid in summer but do not hatch till spring

In the country districts in the winter it is not unusual to see a medium-sized white butterfly in houses when it is very cold outside. This is the common cabbage butterfly which long ago was introduced from Europe and now is all too common here. The caterpillars live on cabbages and when full grown crawl away and form the chrysalids on any firm support, on fences, on the sides of barns or houses or on firewood. If logs with chrysalids on them be brought into the house the butterflies emerge, and we are treated to the unusual sight of butterflies in winter.

Life, dormant or active, is everywhere about us at all seasons of the year. Just because we do not see it in the winter does not mean it is not there.

On land the activity of most living things, such as the very numerous insects, the snails and slugs and earthworms, slows down or comes entirely to rest at a temperature of about 40°, or at the very lowest at 32°, the freezing-point of water. But in certain portions of the sea, far down beneath the surface where the sun's heat and light does not penetrate and where it is darker than the darkest night we know, there is perpetual winter with an absolutely unchanging temperature of below 30°, that is, well below the temperature at which fresh water freezes. At the temperature found at these places in the ocean's depths our lakes and ponds and rivers would be solid blocks of ice; but salt water freezes at lower temperatures than fresh, so that in these frigid depths no ice is formed.

Along the western shores of the Okhotsk and Japanese seas there is a broad band of this very cold water, and within it life is so very abundant as to challenge comparison with any other region in the world. There are various other regions where the sea bottom is just as cold as it is here, or even colder, in the Arctic and Antarctic Oceans and in the deep waters of the Norwegian Sea. In all these places, with temperatures ranging between 28.4° and 32°, animals are

especially abundant. Millions and millions of animals, living on and over large areas of sea bottom, spend their entire lives in a temperature colder than that of the cakes of ice in our refrigerators. They live in full activity and enjoyment at temperatures at which most of the life on land is dormant.

Life is full of paradoxes. On land not all the weak and feeble things are dormant in the winter. In the colder parts of the northern hemisphere there is a strange insect, a wingless kind of crane-fly or daddy-longlegs, which reverses the usual habit of insects by living in summer as a grub or larva under decaying leaves and becoming an active adult in the very coldest months of the entire year. These insects are most active in cold snowy weather from January to April, even when the temperature is below zero, running rapidly across the surface of the snow in perfectly straight lines. In April it has been noticed that if in the morning the sun shone brightly, causing a slight thaw, few of these insects would be visible. But if in the afternoon the weather changed and became colder with a flurry of snow, then large numbers would come hurrying from all directions. These insects are very sensitive to warmth, and will die in a few minutes if held in a warm hand. There is another insect belonging to an entirely different group, a wingless panorpid or scorpion-fly, looking somewhat like a small grasshopper, which has similar habits.

One of the commonest, most conspicuous and most active of the insects seen in winter is the so-called snow-flea, which is in no way related to the fleas. But this is only seen when the temperature rises above the freezing point.

Winter is an interesting season. In it the speed of life slows down—life largely comes to rest. But though it sometimes pauses, life never stops. No matter how cold and bleak it is in the woods and fields, abundant life is always there ready to resume activity with the coming of the spring.

APPLIED GEOGRAPHY

By Dr. ISAIAH BOWMAN

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An American humorist once wrote a book called "Simple Jography." Whether or not modern geography is simple, we leave to the opinion of a generation that has had to learn to pronounce Wooloomooloolоo, Australia, and those strange names which the world war brought into daily use for a time. If we were deprived of Kut-al-Amara one day, we were sure to have Przemyśl or S. Giovanni di Medua in its stead. There have been so many practical applications of geography that it now stands in the company of chemistry and biology in its usefulness to man. I therefore prefer to say "applied geography," not just "geography," when talking with those practical persons who always ask, "Of what use is it?"

Since the motto of geography is "Ubique" (everywhere), we might take a look at the globe before we inquire about practical matters. Had you lived in the Middle Ages you would probably have thought, like most of your neighbors, that the earth is flat in spite of what a few scholars had been saying for 2,000 years about a round earth. It is only common sense to say that it is flat if you see but a little piece of it and do not look too closely. But it was discovered before the beginning of the Christian era that in going from Greece to Egypt, across the Mediterranean, low-

lying stars disappeared beneath the northern horizon and others appeared to rise above the southern horizon just as they ought to do if the surface of the earth is curved. A famous Greek scholar even attempted to measure the earth and made so good a job of it (three hundred years before Christ) that his result is fairly accurate and his principle is in use to-day. But he had no way of knowing if the earth were really round and whether round all the way and any way you measure it When Columbus began his voyage he thought the earth round: he had not proved it so It remained for Magellan to sail around the globe by instalments on two different expeditions Even then the earth might be shaped like a spindle for all he knew Indeed, surveys late in the seventeenth century measured arcs of meridian in France, and through error the conclusion was reached that the earth is spindle-shaped. There were not lacking explainers who said that this was due to the piling up of ice and snow in the polar regions

The French Academy at last sent out two expeditions in 1735 to settle the question—one to a frozen lake in Lapland in a high latitude and another to a valley in Ecuador near the equator It was these expeditions that first established the now familiar fact that the earth is flatter as we approach the poles. Sailing charts and maps to-day reflect the utmost refinements of measurement of the earth's shape and size. This knowledge and what we have learned of the motions of the earth have been applied to the arts and inventions of man in great number—the length of the meter which was designed to be one ten-millionth of the distance from equator to pole, weather forecasting which takes account of the deflection of winds in a cyclone, and even the drawing of many of our state, county and farm boundaries. Our most recent maps of the polar regions, where discovery has not yet caught up with national ambition, show the boundaries of "dependencies" following meridians into unexplored wastes, as in the Ross Dependency and the Falkland Islands Dependencies, and no doubt also in the newly announced "Australian Sector" of Antarctica. No long-range gun in the navy or the coast defense would ever hit a distant mark if account were not taken of the earth's rotation and a slight allowance made for it in calculating the direction of fire

Many are the practical applications of geography in forecasting storms, in predicting the height of tides years in advance as calculated by a marvelously complicated tide machine. through maps and charts in daily use by tens of thousands of travelers, by the study of river and mountain boundaries in the troubled areas between nations and through the study of the rising or sinking of our uneasy earth, on whose coastlines some of our great cities are built. Benjamin Franklin's discovery of the Gulf Stream and its effect on the routes of sailing ships from England to America is one of the great stories of applied science. The history of geographical science is a panorama of revelations about an unendingly wonderful and beautiful earth that is always as new as its newest discovery

But these are of necessity practical days for all of us, and so I wish to speak particularly about a chapter in applied geography of importance to every man, woman and child in the United States—the use of so-called marginal land. The new administration at Washington has one overshadowing responsibility, to improve the lot of the farmer. One of our greatest difficulties is over-production. Many farmers are obliged to sell their grain crops at prices far below cost. The cause is in part a geographical question; to find a cure we are required to take account of the geography of the West particularly. There is no more inspiring process in our history than the west-

ward spread of people over our central Great Plains and to the Pacific. In the nineties the sweep of settlement was slowed down, but it was not stopped Even to-day in parts of the High Plains of western Kansas and Nebraska and eastern Colorado and Montana, virgin grassland is being plowed for wheat I saw the advance of the plow in Colorado and Kansas as late as the summer of 1932 and much more of it in 1930 Even the low price of wheat has not yet prevented new plowing Droughts only temporarily halt it The reason is that Western wheat farmers have learned a trick—how to put big machines on cheap land and by "dry-farming" raise crops that can be sold at a profit This was true even in the discouraging markets of 1930 and 1931, when the price dropped to 60 cents a bushel At 30 cents and less all calculations went wrong and commercial wheat-farming fell into a state of paralysis

The wheat lands on the drier border of the plains country are among the marginal lands of agriculture and in their "continuing wise use" geography becomes an adjunct of statemanship. No government can frame a long-range policy of real value unless account be taken of the peculiar geographical qualities of the marginal lands I have called them pioneer lands, because a pioneer is an experimenter and in the marginal lands experimentation is the first law of survival. It was by experimentation that dry-farming was learned and the edge of the wheat belt pushed forward over the High Plains of Texas and carried west of central Kansas and Nebraska several hundred miles It opened central Washington and northern Oregon and scattered wheat fields through a half dozen Western states where only cattle ranges were known before. The use of more drought-resistant breeds of wheat helped the process vastly.

To some degree all of us everywhere are experimenters. New conditions face us daily. Galsworthy has reminded us "that the *status quo* is of all things the most liable to depart; the millennium of all things the least likely to arrive." But experimentation in the marginal lands is carried much farther than elsewhere. We, of the better-favored regions, have to adjust our minds to the fact, otherwise we miss the significance of the agricultural disease that is now epidemic in the United States, particularly in the West. At the root of that experimentation is climate Nature takes a hand in the Western wheat-growing lands and adds to the farmer's burden, withering his crop by drought and sun or beating it down by hail. The recent Red Cross report on the drought of 1930 and 1931 describes it as a "major disaster," to which was added in parts of South Dakota and Nebraska the most destructive grasshopper plague in the history of those two states

Our rainfall in the East may vary by several inches or by many inches from year to year, and we complain perhaps that the season has been too dry or too wet, when we are really very little inconvenienced by the change How differently we should feel if our rainfall were 22 inches one year and but 7 the next! In such a locality there is moisture enough to permit a heavy crop one year and so little the next year as to result in complete failure There would be no crop at all if wet and dry years came in a wholly irregular fashion, because no one would risk seed and labor. It happens, however, that both wet and dry years commonly come in groups. This means that grain and hay can be stored for use in bad years or reserves of cash built up to buy feed for live stock or to hire additional pasture. Even this would not be sufficient to enable the marginal farmer to survive if it were not for the fact that as a rule he has bought his land cheap or homesteaded it at little cost, except for the "improvements" required by law. It is also in

his favor that the taxes are relatively low because most marginal-land counties are new and thinly settled, with no large cities; and schools and other expensive machinery of civilization have not yet been developed to a state of burdensome luxury. Assessed at first as grazing land, some of the marginal wheat land is only beginning to rise in value, and the tax gatherer has not yet fully caught up with the pioneer.

The droughts and low wheat yield on dry land do not drive out the farmer, for he knows that wet years will come again and in the meantime he enjoys a relatively low tax rate But the whole system was worked out, largely during the period just before and just after the world war, when wheat was still commanding a good price. When both wheat and cattle dropped in price, not to half but to a third or a quarter of the prices that prevailed in the dry-farming boom, the marginal farmer had to face both the exceptional risks of climate and a demoralized market. If he owed money for improvements or for additional land or for live stock and seed, he was caught between two fires. In one such county four fifths of all the families (4,500 in number) in an area as large as the state of Connecticut have appealed for Red Cross aid.

Science does not stand still in the face of such a desperate situation. It is not sufficient to feed people in distress; it is the business of government to find a cure based on sound scientific work. The Conservation Board of the U. S. Geological Survey has been at work for a number of years on the classification of the land in a broad strip east of the Rockies and running all the way from the Canadian boundary south to the panhandle of western Oklahoma. The results are shown upon a most valuable series of maps. Similar maps are now in preparation for the Great Basin covering a territory of equal extent. These maps may be called "risk maps." They show what degree of risk is involved in the use of the land as one goes from the belt of good soils and more reliable rainfall to the belt of poor soils and quite unreliable rainfall. Were these maps followed they would vastly decrease the risks and the suffering now so prevalent in the region. But the dry-land farmer is an inveterate gambler. Again and again farmers have paid their debts and saved up cash in years of rainfall and plenty in areas marked on the land-classification maps as very risky. It has not been feasible and possibly not even desirable hitherto to say to a farmer, "You shall not farm on a given territory because we believe you will fail."

The use of the marginal lands has greatly increased the wheat output of the country and helped lower the price of wheat. They now represent areas of extreme distress. What is the policy to be followed in using them more intelligently? Here science can not complete the story. To say what shall be done with the marginal lands of either Kansas or New York State is a social and political question in part. It involves the standard of living of the marginal farmer and the policy to be followed in forcibly limiting production or changing the use of the land by law. Science leaves that to policy-makers, assigning only to itself as science the duty of analyzing the situation, mapping the belts and the degrees of risk, and explaining how communities are related to the land and to each other.

This might be called the geography of internal affairs. It is a quite different type from that which deals with far-off and perhaps uninhabited lands newly discovered or of never-failing romantic interest. Who has not his land of dreams which he wishes to see some day —Patagonia, perhaps, or the South African veld or the mountains and deserts that have called men through the ages? This was the urge that sent Marco Polo across Asia to far China and

led Ibn Batuta, an Arab of Tangier, six hundred years ago, to travel 75,000 miles through the East, and that impelled Rasmussen, the Danish explorer, to travel on foot and by dog-sled about 25,000 miles in three years on a recent journey from Greenland to Siberia across northern North America. But there is also a practical aspect to geography which analyzes the soils and climates of our own countryside and the communities and neighborhoods of which we are a part. If it leaves the solution of the problem of marginal lands to other agencies of society, such as Congress, at least it constructs a scientific framework of facts and explanations. It also supplies imagination with respect to alternative possibilities, a highly important step on the way to a solution

DANGER SIGNALS IN CANCER OF THE STOMACH

By Dr. WALTER C. ALVAREZ
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TO-DAY cancer stands second as a cause of death. Not only we physicians but also you laymen are becoming more and more concerned over the increase in the incidence of the disease. We all must agree that the first step in fighting this or any other menace is to learn to recognize it early.

Where I work, hardly a day passes but some poor man or woman comes in with a hopelessly advanced cancer of the stomach. Our hearts are wrung by the misery of these people, and we keep asking ourselves: "Why do they wait so long to learn what is the matter; or, having learned of their danger, why are they so slow to deal competently and intelligently with the problem? When their very lives are at stake, why will they waste time with half measures? Why don't they more promptly seek out the physicians with special skill and training who are to be found in every large city of the land?"

Before attempting to answer these questions I must first admit that in many cases the poor victim is doomed some time before he knows that he is ill. Cancer cells grow so silently that often the disease is far advanced before any recognizable symptoms are produced. In such cases there is little that science can do to help.

In many other cases, however, the symptoms appear early enough, but the patient does not realize their significance; he is not worried about a little indigestion, and for a year or more he drives unconcernedly past the most ominous danger signals. Obviously, what the intelligent layman needs most is information in regard to what these signals are. He needs to know when to get worried and when to have a careful examination made of the stomach.

But before I can describe these ominous symptoms some of you already are doubtless saying: "But what is the use of bothering? If a cancer ever grows in me I will die of it no matter what is done." Unfortunately this feeling of hopelessness is wide spread, and it constitutes one of the greatest handicaps in the treatment of cancer to-day. It accounts for so many of the failures of patients to seek help when they are in the curable stage of the disease. Too often they go late, only when they are driven by pain or by the insistence of relatives.

God grant that in the next few years, with the help of the committees made up of devoted and intelligent lay people, we physicians can overcome this paralysis due to fear and hopelessness, much as, also with your help, we have overcome

similar feelings in regard to tuberculosis. To-day the word tuberculosis does not strike the same terror into the hearts of men that it did when I was a boy. We now have learned to recognize the disease promptly, and we know that, taken in the early stages, it is usually curable. Also, when I was a boy, tuberculosis was a disease to be ashamed of, to keep covered up and secret. To-day many people are ashamed to admit that a relative has cancer, but they are no longer ashamed of tuberculosis.

Soon you are all going to learn what we physicians know now, and this is that cancer in many parts of the body is curable. All that is needed is that when you fall ill you come in early enough so that the growth can be removed surgically, or destroyed by x-rays or radium, before it has grown into all-important organs, or before it has scattered all over the body. One dandelion in your lawn is easy to remove, but if you wait a few years until it has seeded itself all over the place it is hard to get out.

Actually, at the present time the average patient with cancer of the stomach, seen by a consultant or an abdominal surgeon, has had troublesome symptoms for a year or more: a most precious and unrecallable interval in which the growth has been given every chance to enlarge and spread.

We all know now that the time to cure tuberculosis is before the patient has a cough or has lost any weight. We want to put him at rest as soon as he feels weak and tired and below par. Similarly, people must learn that the time to treat cancer of the stomach is when the patient still looks healthy and perfectly well. Naturally, when cancer is beginning as a little ulcer or nodule it is too small to have any influence on the health of the patient. But it grows and grows until finally it interferes with the progress of the waves over the stomach and thus causes discomfort; or it grows into nerves and causes pain, or it blocks the outlet of the stomach and causes vomiting, or it bleeds enough to cause anemia and weakness. If only the sufferer would seek out a specially qualified physician the minute such symptoms appear he could more often be operated on with some probability of success.

Actually, the type of patient with cancer of the stomach whom consultants see to-day is often a thin, pale, weak, apathetic old man. Commonly he has a lump in the pit of his stomach, and one learns that for weeks he has been living on little but milk and soup. A year ago he may have been perfectly well, or he may have had a slight accident, or he had what was called intestinal flu, or he worried over the loss of some money or the death of a relative. These things lowered his resistance a little and made him more sensitive, and then he noticed that, for the first time in his life, his stomach didn't feel right after meals; it hurt him, and gradually he became afraid to eat. He went to the drug store and bought some tablets which some one told him were good for indigestion. For a while he was better, but then he got so bad he decided to consult the good old family doctor, who had often been a friend in need. Unfortunately cancer of the stomach was out of this doctor's line; years ago, when in college, he had been taught to recognize the disease only in its final stages, and it didn't occur to him to search for such serious trouble in a well-nourished, ruddy-looking man. Besides, he hated to put his friend to a lot of expense, so he did little more than prescribe some medicine. Later, when this didn't work, he tried another medicine and a diet.

Then the patient went to another physician, who had him x-rayed and found what he thought was a harmless ulcer of the stomach. For the next few months this was treated and every one was encouraged. But one day the patient vomited some blood, or perhaps he discovered a lump in the abdomen, or else

it gradually dawned on the family that he was wasting away, and at last he was taken to see a physician who specialized in diseases of the stomach.

After a careful examination this physician refused to hold out much hope, but advised an exploratory operation because of the bare possibility that the growth might still be removable. But it was not, so the abdomen was quickly closed, and the poor man went sadly home. He was not given x-ray treatment because, unfortunately, this is seldom of much use in cases of cancer of the stomach.

As the patient's sufferings increased, the family decided that something had to be done, and since no honest physician would promise anything, they turned to a quack, the one man who absolutely guaranteed a cure. His price of one thousand dollars, prepaid in cash, was pretty stiff, but who wants to haggle when the life of a loved one is at stake. So another mortgage was placed on the farm. the quack's medicine was tried for a few weeks, and then the inevitable end came.

In a few cases the patient who has had more or less indigestion all his life, or for several years, will develop cancer of the stomach, and he will then have what physicians call a long history. Occasionally this history suggests that the patient first suffered for a few years with an ulcer of the stomach, and then cancer came; and sometimes, on looking back, the patient will remember that at a certain time the symptoms changed in character or became decidedly more severe. But by far the commonest and most typical history of cancer of the stomach is the short one. The patient says, "Doctor, I never knew I had a stomach until this trouble began," or "All my life I could digest tacks, and now I can not stand milk."

Obviously, then, we must always be anxious whenever a person who has been perfectly well for years suddenly begins to have indigestion, or begins to fail in health, and we must be anxious even when there appears to be some slight cause for the symptoms. The danger signals are flying, and we must not be so ready to assume that the trouble is all due to nerves or worry. Young people commonly get nervous indigestion, but older men and women rarely do. It should be obvious to any one that the stomach that has been strong enough to tolerate without complaint the dietary abuse and the worries and anxieties of thirty years of adult life is not likely to be bowled over by anything short of some serious disease, such as cancer, gallstones or failure of heart or kidneys

To sum up, then, we must worry most about the indigestion that comes out of a clear sky in persons past middle life. Cancer of the stomach is very rare before the age of thirty years, and it is commonest after the age of forty.

The question next arises: When such indigestion or failure in health comes, what is to be done? Obviously the patient must have an immediate examination, and this must be made carefully by a skilled physician Many people keep putting off this visit to the doctor because they think only of cancer and do not know that perhaps an ulcer or a gallstone or a tired heart may be causing the symptoms. As a result, they go on suffering for months in an agony of fear, only to discover in the end, either that there was nothing to be so frightened about or else that they have thrown away their one chance of recovery.

But what is a man to do if he has always had some indigestion? How is he to protect himself from that insidious type of cancer which grows silently until long after it has scattered all over the body? There is only one way in which older people might perhaps protect themselves to some extent from this silent enemy and that is by having, at least once a year, an x-ray examination made of the whole digestive tract. The

ordinary yearly check-over of heart and lungs and kidneys is not complete enough to rule out the presence of cancer. Unfortunately, few people are now willing to go to so much bother, even when they can afford the expense, and frankly, I fear it will be a century at least before even educated and well-to-do people will face this problem squarely.

Finally, a word to those of you who have been told you have an ulcer. If your physician can assure you that this ulcer is in the duodenum, just beyond the stomach, you need not worry about it's being cancerous, because cancer of the duodenum is a very rare disease. If, however, the x-ray examination showed the ulcer to be in the stomach, if it was a large one, if you are past middle age, and especially if your symptoms have appeared only recently, the safest thing your physician can do is to assume that you have a cancerous ulcer, until this can be disproved.

Unfortunately, there are only three ways of telling a cancerous from a harmless ulcer; the first, and now most commonly used method is to let the patient drift on with medical treatment until he either gets well or dies; the second method is to excise the ulcer at operation and examine it under the microscope, and the third method is to treat the patient medically and watch with the x-ray every two weeks to see if there are signs of healing. If within a month the ulcer has not shrunk in size, or if it has enlarged, the probability is that it is cancerous, and the only safe thing the patient can do is to go to some center where he can find a surgeon skilful enough to remove the lesion together with part of the stomach.

Not all the patients so treated stay well, but enough of them do so that the gamble is worth taking. Besides, if a man has a cancer he must either take this gamble or else resign himself to the inevitable. Unfortunately, many persons at first refuse the operation: they want first to try a faith cure or some form of quackery, or they say they are resigned and hopeless, and they do not want to be bothered. I would willingly grant these people the right to make this decision if only they would abide by it; the trouble is that, later, when pain and discouragement come, many return demanding that something curative be done, and then it is too late.

To sum up again, I will say that whenever a man or woman, past middle age, begins to suffer with indigestion or symptoms that suggest that something has gone decidedly wrong with that previously satisfactory and uncomplaining piece of machinery, the body, he or she had better seek expert advice immediately, and then follow it.

Finally, may I express the hope that in what I have had to say I have not added to the painful burden of worry that many poor people carry all the time. Why should some of us worry ourselves sick over cancer or heart disease or Bright's disease, or any other disease. When our time comes we must go some way, and for all we know it may be an automobile that runs over us. I believe in being watchful, but I think we should refuse to worry or to cross our bridges until we come to them.

THE VALUE OF INSECTS TO THE CALIFORNIA INDIANS

By Professor E. O. ESSIG
DEPARTMENT OF ENTOMOLOGY, UNIVERSITY OF CALIFORNIA

INDIANS probably knew a great deal more about certain facts concerning the natural instincts and habits of insects than the white race will ever know. The aborigines of California literally lived with their tiny six-legged brothers and liked them in more ways than one Apparently there were no feelings of rivalry on the part of the red men as is so often expressed to-day by the entomological economists who class insects as man's greatest rivals on this earth. The Indians accepted nature as it was without carrying out any ambitious schemes to replace the forests and the prairies with cultivated fields and great cities. Theirs was the lot to live with and enjoy the bountifulness and beauty of the natural paradise from which they exacted only the barest necessities of immediate life. That they had an intimate knowledge concerning the intricate life habits of insects may be inferred from the meager bits of information gathered by anthropologists in entirely different fields of science. Unfortunately the interest in Indian entomology came too late to communicate directly with these aboriginal seers of nature and what they may have gleaned by sharp-eyed and patient diligence throughout the ages has forever perished with them The few entomological scraps which have fallen from the tables of anthropology are meager indeed, but they may serve to stimulate our imaginations of what might have been.

Insects played a conspicuous part in the legends of the California Indians.[1] The Mohave had a story concerning termites which indicates that they knew the subterranean and aerial as well as the wood-destroying habits of these rather obscure white ants. The coastal tribes of northwestern California looked upon the sand cricket[2] with almost human regard This insect was supposed to have brought mortality to man, when he might otherwise have remained immortal. Flies are said to have first taught the savages how to mourn and cicadas how to wail.

Lice enter into a number of Indian legends. In one case the common hero coyote, after the earth emerged from the primeval flood, failing to find mankind, married a louse from whose eggs sprang many tribes.

There is a Yokut myth concerning the origin of the Pleiades. It is a little story of a flea and five girls whom the insect married and subsequently followed into the sky. "That is why there are five stars now in the Pleiades and one at the side. That one is he, the flea."

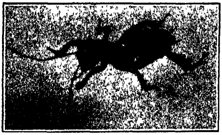
In spite of the ancestral beliefs and legends concerning lice[3] and fleas[4] the Indians were somewhat annoyed by them. I say somewhat because, as a matter of fact, the savages were apparently hardened to these pestiferous foes of mankind and actually gave them little thought or attention. However, they did try to dislodge them from the hair

[1] E. O. Essig, "A History of Entomology," Macmillan, 1931. (Contains a chapter on Indians and insects).

[2] *Stenopelmatus longispina* Brunner, *S. fuscus* Hald. and *S. pictus* Scudd.

[3] The common head louse, *Pediculus capitis* DeGeer was undoubtedly the species.

[4] It can not be definitely established that the flea in question was the human flea, *Pulex irritans* Linn., but it was the commonest of the earliest species observed in the state.



THE SAND CRICKET, *STENOPELMATUS LONGISPINA* BRUNNER,
HAS A SINGULARLY HUMAN-LIKE HEAD AND WAS THEREFORE GIVEN ALMOST HUMAN CONSIDERATION BY THE WESTERN INDIANS. (FROM "A HISTORY OF ENTOMOLOGY," MACMILLAN, 1931).

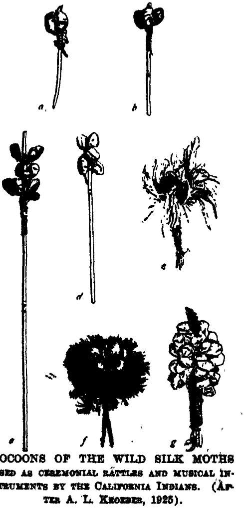
on the head. The Mohave Indians plastered their scalps with mud to kill the vermin. Among all the natives, the sweat houses and frequent plunges into the streams and lakes were also resorted to as a means of shifting the parasites. But at best only the active forms were removed and the eggs remained to furnish a new supply of tormentors in a very short time. By firing their huts countless numbers of the pests were killed, but the Indians overlooked those which were carried on their own bodies into the new abodes.

In ritualistic ceremonies and for musical instruments, many tribes in middle and northern California used the cocoons of the giant wild silkworm moths[5] for rattles. These cocoons were split open, the chrysalids removed, a few pebbles inserted, and then bound singly or in numbers to the end of a stick often further ornamented with feathers.

Few arts were to be found among our west coast aborigines. There was little or no pottery, but basket weaving attained a high state of perfection. The baskets in which they cooked were made water-tight by coating them with wax obtained from several species of coccids,[6] or scale insects closely related to the famous lac insect of India, from which commercial shellac is produced. Insect wax was also used for fastening the sinew backing of bows and even for chewing gum.

Fashionable Mohave Indian women painted their faces in butterfly patterns in red and yellow with artistic ability.

Insects appear to have been most useful to the California Indians as a source of food. When we remember that these red men ate very little real meat and that many tribes were poor hunters, it is not to be wondered that they ate everything that came their way. Professor



COCOONS OF THE WILD SILK MOTHS USED AS CEREMONIAL RATTLES AND MUSICAL INSTRUMENTS BY THE CALIFORNIA INDIANS. (AFTER A. L. KROEBER, 1925).

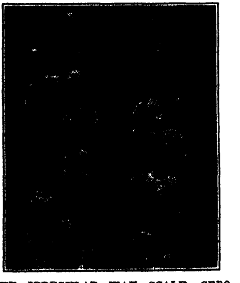
[5] *Samia euryalus* (Bdv.) and *Telea polyphemus* (Cramer).

[6] *Tachardiella larrae* Comst., *Ceroplastes irregularis* Comst., *C. quercus* Comst., and other species.

Kroeber, of the University of California, states that the "California Indians are perhaps the most omnivorous group of tribes on the continent"[7] Along the coast and streams fish, eels and shellfish were conspicuous articles of diet. But in the valleys acorns formed, by far, the most important item. Then came seeds, bulbs, roots, berries and other vegetable products. Small animals, chiefly rodents and insects, supplied most of the proteins and fats. A great number and wide variety of insects were eaten, either raw, dried, roasted or otherwise prepared.

The young fat larvae of bees, wasps, ants and wood-boring beetles were a delicious relish not often overlooked by the ever hungry boys and girls. White grubs from the sod, termites from decaying wood, crane fly larvae or leather-jackets from the wet earth and maggots from many sources were similarly sought as ready-to-eat commodities of the diet.

[7] A. L. Kroeber, "A Handbook of California Indians," Bur. Am. Ethnology, Bul. 78, 1925



THE IRREGULAR WAX SCALE, *CEROPLASTES IRREGULARIS* COMST.
THE BODIES OF THE FEMALES ARE SURROUNDED BY A THICK COATING OF WAX WHICH MAY BE REMOVED BY BOILING WATER. THUS SOFTENED THE WAX WAS USED FOR WATERPROOFING BASKETS AND FOR MANY OTHER PURPOSES BY THE INDIANS. (FROM "A HISTORY OF ENTOMOLOGY," MACMILLAN, 1931).

THE FAT LARVA OF THE CALIFORNIA PRIONUS, *PRIONUS CALIFORNICA* MOTS.
A WOOD-BORING INSECT MUCH RELISHED BY THE WESTERN INDIANS. (FROM "A HISTORY OF ENTOMOLOGY," MACMILLAN, 1931).

Aside from that obtained in the native fruits and berries, sweets were available in the form of the so-called Indian honey or honeydew, the excrement of plant lice, coccids and a few other homopterous insects Small quantities of honey were to be found only in the nests of bumblebees and some other wild bees, since the honeybee was unknown in California until it was introduced by the American settlers only eighty years ago

Grasshoppers[8] were universally eaten wherever available, and in the large interior valleys and along the foothills of the Sierras they often occurred in immense swarms. Then it was that the entire Indian populace turned out to gather a large part of the winter's food supply. Several methods were employed to capture the insects, but usually a fire was first built on level ground or in a pit, and when reduced to coals the drive began from afar. In an ever contracting circle the Indians beat the ground and

[8] Many species were eaten, chief of which were, *Melanoplus devastator* (Scudd.), *M. altanis* (Riley), *M. femur-rubrum* (DeGeer), *M. differentialis* (Thomas), *Œdaleonotus enigma* (Scudd.), *Camnula pellucida* (Scudd.) and *Schistocerca venusta* (Scudd.).

CALIFORNIA INDIANS
DRIVING GRASSHOPPERS INTO A FIERY PIT TO KILL AND ROAST THEM FOR FOOD. (AFTER J. M. HUTCHINGS, 1888).

vegetation with bushes and finally forced the bewildered grasshoppers into the masses of coals, where they were quickly roasted and subsequently stored away in bulk or impaled or strung on sticks to be eaten as we might dispose of roasted peanuts, or to be ground into a meal and mixed with pinole, or acorn meal, and boiled in baskets with hot stones. Literally tons of hoppers were thus consumed, but the annual supply never seemed to diminish for locusts were among the most serious pests which devastated the fields, orchards and gardens of the early white settlers throughout the state.

Yet another interesting insect food, still collected by the Indians in the Mono Lake region, is the pupa of a small fly[9] which breeds in unbelievable numbers in certain portions of the brackish waters of Mono Lake and other saline lakes in eastern California and western Nevada. In late summer the pupae of the fly are washed upon the shores of these lakes in great windrows. The edible part consists of a small fat body about the size of

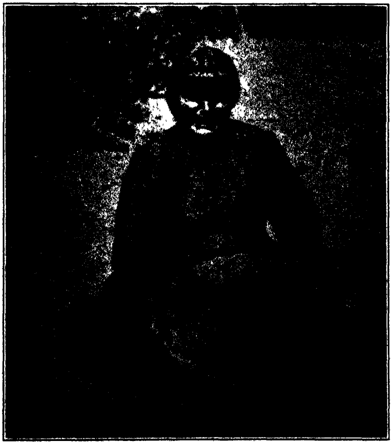
[9] *Ephydra hians* Say.

LARVAE AND PUPAE OF THE PANDORA MOTH, *COLORADIA PANDORA* BLAKE, WERE BOTH ROASTED AND THEN EATEN BY SEVERAL TRIBES OF WESTERN INDIANS LIVING IN THE YELLOW PINE BELT OF THE SIERRA AND CASCADE MOUNTAINS. (FROM "A HISTORY OF ENTOMOLOGY," MACMILLAN, 1931).

a kernel of wheat, which is readily separated from the protective outer skin by rubbing the pupae between the hands. Nor were the squaws too particular to separate the kernels from the chaff. The material thus collected was called *kootsabe* and, in addition to becoming rancid and odorous, would keep for months and could be eaten without further preparation like raisins or popcorn. Very great quantities have been collected even to the present time.

Another astonishing food product still utilized by the western Indians is the large caterpillar of the pandora moth,[10] which feeds on the needles of the yellow pines of the Sierra and Cascade Mountains. The full-fed caterpillars are from 2 to 2½ inches long, or almost as large as your index finger. They live in the pine trees far out of reach—and only descend to the ground to enter the soil to pass into the chrysalis or pupal stage. Therefore the Indians were either compelled to await their natural descent or to resort to some means of forcing them to drop off. This they did by building a fire under the infested trees and making a smoke smudge to stupify the caterpillars which rained to the ground These were gathered in baskets by the women, children and old men, killed and dried in a bed of hot ashes, coals and sand, and

[10] *Coloradia pandora* Blake.



INDIAN WOMAN PARCHING CATERPILLARS BEFORE A FIRE

IN THIS MANNER THE HAIRS WERE REMOVED AND THE INSECTS PREPARED FOR EATING.

(AFTER A. L. KROEBER, 1925).

A WINDROW OF THE PUPAE OF THE KOO-TSABE FLY, *EPHYDRA HIANS* SAY, WASHED UPON THE SHORE OF MONO LAKE AND UTILIZED FOR FOOD BY THE INDIANS OF THAT REGION. (AFTER ALDRICH, 1912).

stored away for future consumption. After boiling in water, without any seasoning whatever, the resulting pabulum was called *pe-ag-gie* and was fished out by the none-too-clean fingers as serving implements. Hungry whites, who tasted the food, claimed that boarding with the early Californians on the "American plan was not so good."

Other caterpillars, both hairy and smooth, were parched before an open fire by the Pomo Indians of the San Francisco Bay region and served hot or cold, or, if preferred, with less trouble, like oysters on the half-shell.

It might be thought by some of my readers that such insect food is unwholesome. While it might be admitted that most of us would not care to eat grasshoppers, maggots and caterpillars, the fact remains that they are perfectly harmless and wholesome and, if prepared in more modern ways, might even be palatable. Let me suggest that if you are ever lost and unable to secure the customary foods, you need never suffer hunger if insects are available. Even a fire would be unnecessary to prepare a meal under such circumstances.

Regardless of what we may think about the bill of fare of our California predecessors, it must be remembered that all aborigines ate insects and even to-day the abundance of grasshoppers in many old world countries may be ascertained by noting the prices in the local markets.

THE PROGRESS OF SCIENCE

EDWARD LEE THORNDIKE: PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE new president will be claimed as the honored representative of two sections of the American Association for the Advancement of Science, that of psychology and that of education. Thorndike's main fields of investigation are the psychology of learning and the measurement of mental abilities and of educational achievements.

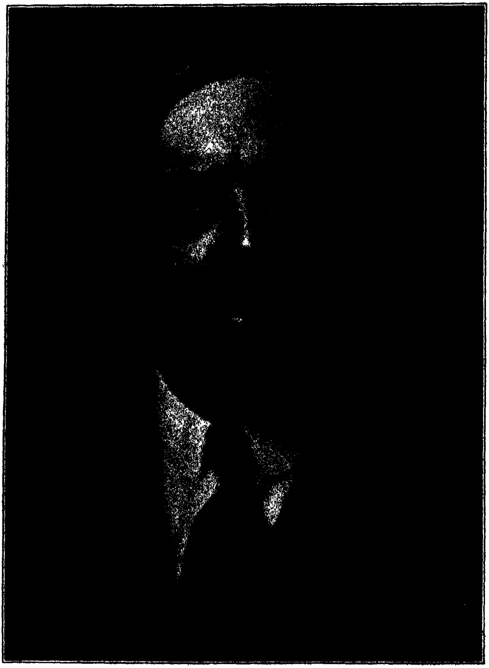
William James in 1896 recognized the promise of the young graduate student who wished to embark on quite a new line of work, the experimental study of animal learning. About a year later, two who have recently been presidents of the association, Cattell and Boas, initiated him into what was then a novelty in psychology, the statistical treatment of test results. One year more, and Dean James E. Russell detected in Thorndike the man who could be the pioneer in a scientific educational psychology, and called him to Teachers College, Columbia University, where his activities have since been centered. From the start he proved himself fully qualified, by his fearless thinking, by his untiring industry in research, by his enterprise and sound judgment alike, for the position of leadership thus intrusted to him.

There was little in existenee in 1900 that could now pass muster as educational psychology or as the scientific study of education. Thorndike seized on measurement, that great reliance of the older sciences, as furnishing the key to scientific progress in education. The objection was raised, and has often been raised since, that human actions and abilities are too fluid and variable to be measured. To this his retort is that "everything that exists exists in some quantity," and that the problem is simply one of devising suitable measuring instruments. Variability must be combatted by statistical methods. So it came about that a man who was not primarily a mathematician, by any means, became the leader of educators in the use of statistics. What specially characterizes his large volume of statistical work is something that is often lacking in the mathematical statistician—a keen sense for reality and concrete probability.

Among the measuring instruments developed with rare skill by Thorndike are scales for measuring excellence of reading, English composition, handwriting and drawing and intelligence tests for various age levels, including that of college entrance. He uses these instruments not only for practical education and vocational guidance, but in research on individual differences, the influence of heredity and the growth curve of intelligence, which he finds continues rising up to the age of 18 or 20. In his "Adult Learning" he has shown that the decline in learning ability from the twenties to the forties is relatively slight, though clearly demonstrable.

Apart from these important contributions to mental and educational measurement, the great mass of Thorndike's discoveries can be brought under the broad head of learning, certainly a central problem in both psychology and education. His object in trying learning experiments on animals was partly that of tracing the evolution of intellect. But he soon saw that his results bore on the general psychology of learning; and in fact this line of investigation, which he inaugurated as a graduate student, has been taken up by many others and furnishes much of our current evidence on the learning process.

The principal conclusion which he



DR. EDWARD LEE THORNDIKE

PROFESSOR OF EDUCATIONAL PSYCHOLOGY, TEACHERS COLLEGE, COLUMBIA UNIVERSITY; ELECTED PRESIDENT OF THE AMERICAN ASSOCIATION

drew from his early experiments on animal learning, a much-debated conclusion which in the past few years he has placed on a stronger basis than ever by very ingenious experiments on human learning, is known as Thorndike's law of effect. An animal placed in a novel and puzzling situation tries a variety of responses till one succeeds, and if replaced time after time in the same situation gradually concentrates upon the successful response. The same course of events at a higher level is seen in human learning. Thorndike shows that one prime factor in fixing the successful response is the glow of satisfaction which it brings.

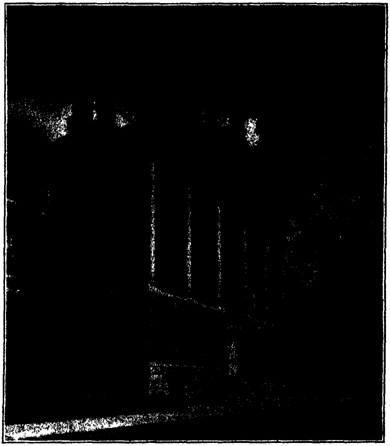
Another problem in learning to which he has devoted much attention goes by the name of "transfer." How much general improvement in memory, in keen observation or in reasoning is to be expected from practise in specific types of memory or observation or reasoning? How far does practise in geometry make one a good reasoner in law? Thorndike's early experiments indicated that the amount of transfer was small, and he applied this finding to education against the then dominant doctrine of formal discipline or faculty training. In recent years extensive experiments on the after-effects of high-school subjects have led him to the conclusion that the only justification for including any subject in the curriculum is the intrinsic value of its subject-matter to the student. A good student will gain from any study which he can take seriously. "When the good thinkers studied Greek and Latin, these studies seemed to make good thinking. Now that the good thinkers study physics and trigonometry, these seem to make good thinkers. If the abler pupils should all study physical education and dramatic art, these subjects would seem to make good thinkers. These were, indeed, a large fraction of the program of studies for the best thinkers the world has produced, the Athenian Greeks."

As these few high points in his work would indicate, Thorndike has always been a center of controversy. He is a first-class controversialist because of his unfailing good temper. He is not, however, primarily a controversialist, but a scientific worker, willing to take any amount of trouble and to go into any amount of detail to establish the truth on a worth-while problem. His painstaking analyses of the pupil's difficulties in such subjects as reading, arithmetic and algebra rank high among the many contributions which have made him a leader in the current effort to improve our traditional educational practise.

R. S. Woodworth
Columbia University

THE BOSTON MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

A young scientist, attending the American Association for the Advancement of Science meetings for his first time, might be confused by the many programs given in widely separated buildings. Those of us who for a third of a century have journeyed to these midwinter meetings, held in different parts of North America, were pleased that the Boston local committee had planned so well to care for the multitude of interests inherent in and associated with this largest of all science associations. The sudden drop to almost record low temperatures did not seriously interfere with the efficient working of the organizational plans, and a decidedly successful series of meetings was enjoyed by thousands of scientific workers. The official program of more than 150 pages

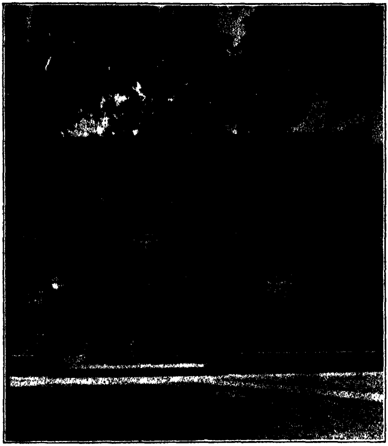


THE MALLINCKRODT CHEMICAL LABORATORY OF HARVARD UNIVERSITY

merely lists the topics that were considered. These topics are the captions of research papers that cover the whole range of scientific endeavors. Obviously, this brief account can do no more than mention a few of the many significant and more general features.

At the opening session on the evening of December 27 Dr. John J. Abel, the retiring president, gave an address on "Poisons and Disease" before a large audience in the Grand Ballroom of the Hotel Statler. President Henry Norris Russell, research professor of astronomy at Princeton University, presided and members of the association were welcomed to Boston by Dr. Karl T. Compton, president of the Massachusetts Institute of Technology, and Dr. Harlow Shapley, director of the Harvard College Observatory. At the close of the program the audience and speakers adjourned to the Foyer, where a general reception was held.

A member of the President's cabinet honored the association by addressing it. Secretary of Agriculture Henry A. Wallace spoke before the entire association on "The Social Advantages and Disadvantages of the Engineering-Scientific Approach to Civilization." It was a fundamental address, the merest suggestion of which can be given by quotations from remarks made near the opening and closing of Mr. Wallace's discussion. In referring to Spengler's



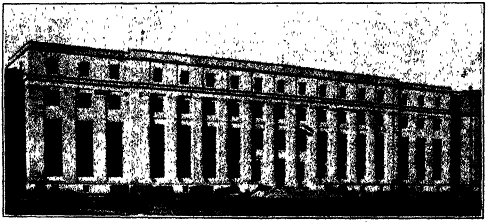
ENTRANCE TO THE BIOLOGICAL LABORATORIES OF HARVARD UNIVERSITY

philosophy of youth, middle age, then decay of nations, Mr. Wallace said: "According to this analysis, a civilization takes its origin in a profound, but as yet unexpressed new attitude on the part of a virile, agricultural people toward the universe. This profound, original feeling gives the bias to subsequent events throughout the life of the civilization. First, it manifests itself in great cathedrals and sculpture, next in painting, literature and music, followed by science, mechanics and wealth, and finally it manifests itself in dissolution, which comes because of a lack of faith in the worth-whileness of the original attitude toward the universe and because of disgust with the material results which have finally been inspired by that attitude. According to this analysis we have now come to the late fall, the eventide of this civilization, and the coming of the engineer is like the coming of Indian summer in late October just before the cold and dreary days of winter."

Then, after a clear and vigorous analysis of the factors involved in the problem, Mr. Wallace closed with: ". . . we wish a wider and better controlled use of engineering and science to the end that men may have a much higher percentage of his energy left over to enjoy the things which are non-material and non-economic, and I would include in this not only music, painting, litera-

THE JEFFERSON PHYSICAL LABORATORY AND THE CRUFT HIGH TENSION LABORATORY OF HARVARD UNIVERSITY

ture and sport for sport's sake, but I would particularly include the idle curiosity of the scientist himself. Even the most enthusiastic engineers and scientists should be heartily desirous of bending their talents to serve these higher human ends. If the social will does not recognize these ends, at this



THE GEORGE EASTMAN RESEARCH LABORATORIES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE AWARD OF THE RUMFORD MEDAL TO DR SHAPLEY
BY THE ACADEMY OF ARTS AND SCIENCES FOR HIS "RESEARCHES ON THE LUMINOSITY OF STARS AND GALAXIES." THE PRESENTATION OF THE MEDAL WAS MADE AT A JOINT MEETING OF THE AMERICAN ASSOCIATION AND THE ACADEMY AFTER WHICH DR SHAPLEY ADDRESSED THE GATHERING ON "THE ANATOMY OF A DISORDERED UNIVERSE" IN THE PHOTOGRAPH ARE PROFESSOR A. E. KENNELLY, CHAIRMAN OF THE RUMFORD MEDAL COMMITTEE, DR. HARLOW SHAPLEY, AND PROFESSOR GEORGE H. PARKER, PRESIDENT OF THE ACADEMY.

particular stage in history, there is grave danger that Spengler may be proved right, after all, and a thousand years hence a new civilization will be budding forth after this one has long laid fallow in a relative Middle Ages." Secretary Wallace's address is published in full in *Science* for January 5, 1934.

Each year, by means of an annual gift from an unannounced donor, the association offers a prize of $1,000 for a conspicuous piece of research reported during the annual meetings. The various sections are expected to decide what papers, if any, of those presented in their sections are worthy of consideration by the association's committee on awards. That committee carefully considers the papers thus recommended to it. This year's prize was voted to Dr. Reuben L. Kahn, of the University of Michigan, in recognition of his discovery of the protective resistance of tissues against disease infection. Dr. Kahn's researches showed that the immunity of the skin is far more resistant, even ten times, than that of the blood, which has previously been regarded as containing the elements that are resistant to disease. The tissues of muscles and of certain epithelial tissues are also shown to possess this protective quality. We have

previously regarded the phagocytes and so-called antibodies of the blood as the chief agents of protection against recurring disease. Such far-reaching discoveries as announced by Dr. Kahn would seem to necessitate many important changes in existent ideas regarding the nature of immunity and the treatment of certain disease. As one of many results of Dr. Kahn's reports, the concept of "antibodies" in the blood and the relations of the blood to protection against disease seems to be in for scrutinizing restudy.

An occurrence of special interest to the writer was the meeting of teachers of the natural sciences, chiefly those engaged in secondary and elementary schools, and teacher-training institutions. The program had been arranged, under instructions from the council of the association by the Committee on the Place of Science in Education. It was thought that many teachers of science might wish to meet during the period of meetings of those who are engaged in research in the various aspects of science. About 125 representatives of at least fifteen science teachers' associations and individual science teachers attended. At the well-attended luncheon, Dr. Merriam spoke on "The Influence of Science on the One Who Studies It" The day's program elicited the request that the Committee on the Place of Science in Education shall prepare another one-day program for science teachers, this to be given in Pittsburgh during next year's meetings. At the request of the chairman of the committee, a cooperating committee of those present was decided upon. Dr. H. A. Carpenter and Dr. W. L. Eikenberry were named on that committee, and others are to be added. This committee, in cooperation with the Committee on the Place of Science in Education, will undertake to prepare the proposed Pittsburgh program.

The newly elected president of the association is Professor Edward Lee Thorndike, of Teachers College, Columbia University. Dr. Thorndike, not yet sixty years of age, has long been recognized as America's foremost student of application to education of the results of experimental psychology. The late Dr. Charles William Eliot was the last president elected to represent education Dr. Thorndike not only represents education, which is Section Q, but has been a leading contributor to research in psychology, which is Section I. He surely is a worthy representative of IQ, and doubtless his election has the wide approval of educators, psychologists and scientists in general.

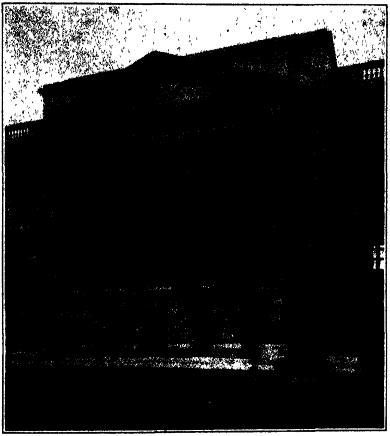
Otis W. Caldwell

THE FELS PLANETARIUM OF THE FRANKLIN INSTITUTE

Forming part of the new building of the Benjamin Franklin Memorial and The Franklin Institute, in Philadelphia, the Fels Planetarium is now open to visitors 31 times a week. On December 5, the planetarium, as well as the rest of the building, was opened to the donors to the Benjamin Franklin Memorial fund, from which the building was erected. The opening of the other sections to the general public will follow in the immediate future.

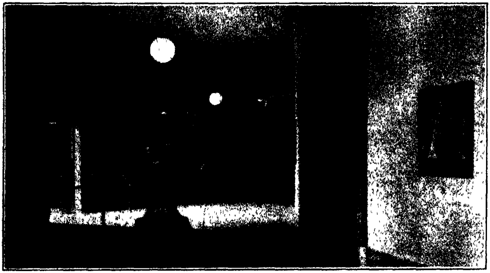
The building is located at Logan Circle, about half a mile from City Hall, and the site occupies an entire block, with an area of four and a half acres. A little less than half of the entire structure has now been erected, including all the east and north façades, each about 370 feet long. The main entrance is on the east, and an impressive flight of granite steps leads through a portico into a large rotunda, which will eventually contain a heroic statue of Benjamin Franklin by James E. Fraser.

On the north side is the Fels Plane-



THE ENTRANCE TO THE FELS PLANETARIUM

tarium, with its own entrance on the ground floor Entering a curved lobby, with terrazzo floor and travertine walls, a number of transparencies of astronomical photographs, made at the Yerkes and Mt. Wilson Observatories, are seen. On one ground-glass screen is shown an image of the sun, formed by a coelostat telescope, with a lens on the roof, 85 feet above. On another screen the phenomena of partial, annular and total eclipses of the sun are reproduced, by means of a specially designed apparatus. At the eastern end of the lobby is a doorway, leading to a lecture hall, and above is a triptych of three paintings by Howard Russell Butler of the total eclipses of 1918, 1923 and 1925. At the end of a corridor on the west side of the planetarium chamber is a globe, also painted by Mr. Butler, representing the appearance of the earth from outer space. Viewing it from one end of the corridor, the museum visitor can see the earth as it would look if viewed from the distance of the moon. In the center of the lobby, just before the main door to the planetarium chamber, is a large orrery, made by Michael Sendtner, of Munich. This is a glass globe, five feet in diameter, on which are painted a number of the brighter stars and the constellation names. Inside are shown the sun and the planets out to Neptune, each rotating on its axis, provided with its satellites and revolving in its orbit.



THE FOYER OF THE FELS PLANETARIUM
SHOWING THE SENDTNER ORRERY, ONE OF THE TRANSPARENCIES AND PART OF THE GROUP OF ECLIPSE PAINTINGS.

Entering the planetarium chamber, one sees the Zeiss instrument in the center. Arranged in concentric circles around it are 500 chairs. The dome overhead, 20 meters in diameter, is made of sheets of stainless iron, each curved to the proper radius These sheets are perforated with holes 1/16th inch in

THE PLANETARIUM CHAMBER SHOWING THE INSTRUMENT IN POSITION

VIEWING THE PLANETARIUM INSTRUMENT
LEFT TO RIGHT. DR. HOWARD MCCLENAHAN, SECRETARY OF THE FRANKLIN INSTITUTE AND DIRECTOR OF THE MUSEUM, SAMUEL FELS, THE DONOR; DR. JAMES STOKLEY, ASSOCIATE DIRECTOR FOR ASTRONOMY

diameter, and 1/8th inch between centers. The purpose of these holes is to permit the sound of the lecturer's voice to penetrate without interference. A large part of the back wall is covered with padding of sound absorbent material, and thus objectionable echoes are completely suppressed. The inside of the dome, on which the images of the stars and planets are projected, is painted white, with a special paint giving very high reflectivity. This is the first planetarium dome to be so constructed, as all the previous ones in America and in Europe have fabric projection surfaces, which are subject to many disadvantages. When soiled, the metal dome can be cleaned, and a fresh coat of paint will restore it to its original whiteness. The paint is sprayed on, and this prevents filling of the holes, with consequent deterioration of the acoustic properties.

The formal opening of the Fels Planetarium took place on November 1, 1933, at 3.30 P. M., before a distinguished audience of invited guests.

Public demonstrations are being given every day, including Sunday, in the afternoon and evening. An additional public demonstration is given at 11:00 A. M. on Saturday. Each weekday at 10:30 and Saturday at 9:30 A. M., special demonstrations are given for the

school children of Philadelphia, who are admitted without charge. A special series for college students in astronomy, to accompany their courses, is being given.

Because so many phenomena can be shown with the planetarium, it is not possible to include them all in a single demonstration. Therefore, the subjects of the lectures will be changed monthly, beginning in January. Lectures are given by the writer and his assistant, Mr. Wagner Schlesinger, as well as by a staff of part-time demonstrators: Professor William H. Barton, Jr., director of the Hyatt Observatory of Pennsylvania Military College; Dr. William L Fisher, assistant curator of the Commercial Museum; Dr. John H. Pitman, of Sproul Observatory, Swarthmore College, and Mr. A. Clyde Schock, the Philadelphia High School.

On an upper floor is the observatory and the astronomical exhibit hall. The principal instruments are a 24-inch reflecting telescope, made by J. W. Fecker, of Pittsburgh, and a 10-inch refractor, by Carl Zeiss, Jena. The latter is the first of its kind in the United States, as it is of the Urania type of mounting, developed at the Zeiss works especially for public observatories. The tube is balanced close to the eye end, and as a result the eyepiece moves through a much smaller range of height above the floor than with the conventional mountings. Thus, it is unnecessary for the observer to climb a high ladder when the telescope is pointed near the horizon. The entire roof above the telescopes slides back, making an opening 22 by 40 feet. This is also of great advantage for a public observatory, as the visitors can see the entire sky, and not a narrow strip, which is visible through the slot in the usual dome. The sliding roof is of steel and glass, weighing twenty tons, and is moved by an electric motor.

In the exhibit room which leads to the observatory are numerous other astronomical exhibits. These include the telescope used by the Yale University Observatory, the oldest in the country, when it was first established in 1830, another by Merz and Mahler, used at the Philadelphia Central High School, beginning in 1839, a meridian circle and a heliometer, loaned by the Yale University Observatory, a synchronome clock, models of stars and planets, additional astronomical transparencies, a painting of the planet Mars as seen from Deimos, painted by Mr. Butler, and the famous orrery made by David Rittenhouse for the University of Pennsylvania in 1871. This historic instrument has been restored to its original condition in the institute's shops, where many of the models have been constructed.

James Stokley
Associate Director for Astronomy
The Franklin Institute

THE SCIENTIFIC MONTHLY

MARCH, 1934

THE PROBLEMS OF THE DESERT

By Dr. FORREST SHREVE

DESERT LABORATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON

THE man of practical affairs looks ruefully at the desert as a great waste place which should be put to human use as speedily as possible. Almost invariably his conception of utility is the prevailing one, which concerns only the physical welfare of man. He sees the possible extension of agriculture, the maintenance of improved grazing ranges, the utilization of natural desert products or the conversion of solar energy into commercially useful forms. The more philosophical student of human needs can see in the desert many uses of a wholly different type—humanistic, intellectual and esthetic. He can see the desirability of having a little-coveted region in which it is possible for people to dwell simply and cheaply, with the opportunity to wander, to think, to paint, to study or to write without noise and disturbance. The economist would doubtless agree that the value of the desert as a living place, a source of inspiration, a field of scientific work, is worth many times its marginal value in the world of commodities.

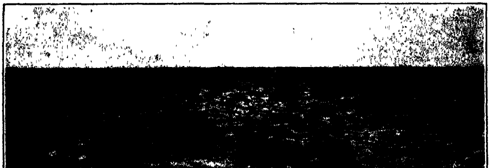
Many features of our civilization were developed in the remote past by desert people of the Old World. It appears highly probable that the human race owes as much of its advancement to the dwellers in the arid lands around the Mediterranean as it does to those of the cool and humid portions of Europe and Asia. In America the aborigines had made their greatest advances in the communities of the desert southwestern states and in the arid portions of Mexico and Peru. The present generation, equipped with the tools of research, faces the duty of learning to know the desert as fully as possible. It must unravel the tangle of reasons for its having been a favorable place for advancement, it must investigate the practical utilities of the desert and must evaluate its higher potentialities for service. It will then remain for the future to determine the ultimate place of the desert in civilization.

In considering the problems of the desert the line of vision falls directly across the boundaries which separate the conventional fields of scientific endeavor. Peculiar to the desert are many of its physiographic processes, its climatic influences, the distribution and character of ground water and soils, the regimen of its streams, the structure of its plants, the behavior of its animals and the culture of its men. A full view of the problems of the desert embraces inquiries into all these. The study of the desert belongs in part to many sciences. Since the aim of eremology is to understand the desert, its history, processes and life, a close interlocking is essential in the work which these sciences contribute to the solution of its problems. As a regional rather than a topical subject eremology takes its place as

a part of the great field of geography. Primarily, both of them deal with natural features, but the ultimate concern of each is the relation of these features to man.

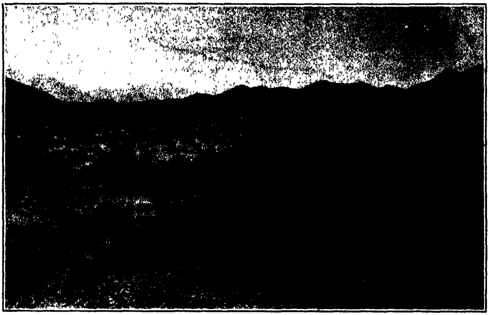
Many of the problems of the desert are intrinsic, while others are common to the desert and to moister regions, but can be attacked in a more effective manner under the clear-cut extremes of the desert. Indeed, it is not always possible to delimit the problems of the arid lands from those of the semi-arid ones, and there is no great importance in doing so. The very term "desert" is a relative one, since the surface of the earth presents a great variety of arid areas, ranging from the most extreme rainless wastes of wind-blown sand or barren rock to regions with a moderate rainfall and a surprising amount of plant and animal life. Throughout this entire gamut of aridity the low and irregular rainfall is the most important item in the physical conditions. However, there is no particular minimum of rainfall and no other single criterion that will serve to distinguish a desert. Ten inches of rain in temperate latitudes will give better conditions than twenty inches in the subtropics. The altitude, the topographic features, the character of the soil, the proximity of the sea and the percentage of cloudiness all serve to modify conditions as much as differences in rainfall do. An adequate definition of desert must be a composite one, embracing both its causal and sequential features. It must be based on the degree to which a scanty and irregular water supply becomes an item of first moment in the life of plants and animals. Finally, its human aspects must be stressed, as has often been done by defining it as any region in which irrigation is essential to agriculture and to permanent settlement based on it. In speaking of the frontiers on which aridity has checked the spread of civilization, Isaiah Bowman has well said: "These are the regions where environment conspicuously affects the lives of men."

The principal aspects of desert investigation are exploration, geological and physiographic work, the study of stream history, of soils, of climatic conditions, of plants and of animals.



ALKALINE PLAINS

OF OTERO BASIN, NEW MEXICO, BEARING ONLY SALTBUSH AND SCATTERED TUFTS OF GRASS.



OUTWASH PLAIN IN THE TULE DESERT,
NEAR THE INTERNATIONAL BOUNDARY IN SOUTHWESTERN ARIZONA. IN THIS REGION A RAINFALL OF 6 TO 8 INCHES SUPPORTS A REMARKABLY RICH PLANT AND ANIMAL LIFE

Scarcely less important than all these is the study of the natural history of man in desert environments, both in the past and the present. The anthropologist and the archeologist can here unite in a study of the habits, culture and practises of early and recent desert races, and the physiologist and geneticist can investigate the influences of the desert environment and the characteristics it may have engendered.

Geographical exploration has shown the location of the deserts of the world and has outlined their boundaries, at the same time that it has done much toward the mapping of their mountains, streamways and other features. In some of the largest and most arid regions, however, there still remains much to be done in the primary phases of geographical work. The investigation of the geological features has been thorough in a few restricted localities and extremely cursory or wholly lacking in extensive areas. Much additional work is needed and promises rich returns in both stratigraphy and paleontology, as is amply illustrated by the results secured by the American Museum of Natural History in Mongolia.

The features of land form and physiographic process which are characteristic of desert areas have received considerable study in Asia, Africa and America. The recent important contributions in this field by Kirk Bryan, Douglas Johnson, Eliot Blackwelder and others show how promising are the possibilities of further work in arid regions. The history of drainage ways and the influences of climate on erosion and deposition need further exhaustive work, particularly with reference to the outcome of climatic fluctuations. More detailed study is needed in additional regions as to the comparative rôle of wind and water in physiographic processes.

In climatology the desert has been

sampled, but its conditions have not been thoroughly investigated except in a few widely separated places The extremes of drought and temperature are better known than their frequence and seasonal distribution. Much has been published on the most astonishing features of certain accessible places, at the same time that very few data are available to show the stages of climatic change that are to be encountered in passing from the heart of the desert across its boundaries into the grassland or savanna by which it is bordered. Every general climatological text betrays the inadequate knowledge of the arid regions, as contrasted with the humid ones. For example, in Geiger's illuminating work on the lowest level of the air, "Das Klima der Bodennahen Luftschicht," little is found about the desert, the very region in which the lowest layers of the atmosphere show the greatest departure from the higher ones. The arid regions, in fact, provide splendid material for effective study of meteorological processes. In them are found rapid changes in temperature of the soil, vigorous convectional movements in the air, sharply contrasting droughts and downpours, all occurring under conditions such that cause and effect can be most easily followed The study of light and of solar radiation in the desert is just beginning, in spite of the fact that sunshine is the greatest and most distinctive natural resource of the desert.

Some of the most interesting and at the same time most complex problems of the desert relate to the plant and animal life which shows itself to be so well adjusted to conditions of great aridity. There is no epic more thrilling than the story of the keenly pursued lines of investigation that gave us our knowledge of the ascent of plants and animals. The morphologist has shown that the sea was the place of origin of life and has traced the lines of development of its organisms with convincing accuracy. The morphologist and the paleontologist have united to give us a picture of the emergence of life from the ocean and its establishment in swamps, marshes and rainy jungles, followed by its rapid adjustment to solid land. An equally thrilling story awaits the reader of the future when it becomes possible for him to have the full narrative of the conquest of the desert by living things. The emigration of life from the sea to the moist jungle is scarcely more astounding than its hegira from the moist jungle to the desert.

The physical sciences seem to have sketched a fairly clear picture of the characteristic phenomena of the desert in their fields when the work that they have accomplished is contrasted with the imperfect outlines of the picture that biology has been attempting to draw.

The geologist has furnished satisfactory evidence that there have been deserts in past epochs, probably extensive and pronounced ones, but he has been compelled to draw his conclusions mainly from the physical character of the deposits then laid down. Deserts have existed since Permian time, appearing and disappearing in different parts of the world The evidences of some of them are found in regions which are now desert Some of the most arid parts of the world have been so for a very long time, but not a great deal is known as to the actual continuity of desert conditions or the possibilities for the persistence of the same types of life through such long periods. The fact that the desert offers such poor conditions for the preservation and fossilization of living remains has resulted in a relatively small contribution from paleontology toward the history of desert areas. Indeed, the fact that moist regions offer such good conditions for the preservation of a biological record may be responsible for some exaggeration in estimating the extent to which moist conditions have prevailed since Paleozoic time.

SHORT-LIVED HERBACEOUS PLANTS

IN SOUTHERN ARIZONA A PERIOD OF COPIOUS RAIN IS FOLLOWED BY THE APPEARANCE OF MANY OF THESE

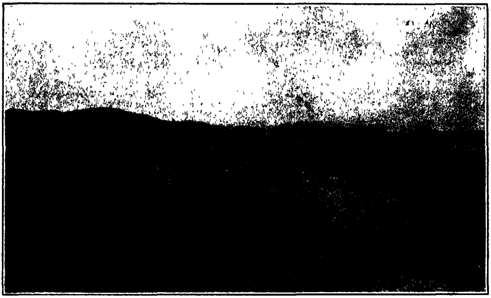
The history of the origin and development of the biota of the desert, that is, of its animals and plants considered collectively, constitutes a problem which is largely a distinct one for each of the great continental desert areas. It has long been known that there are very few species of plants or animals common to the arid lands of America, Africa, Asia and Australia. At the present time these deserts are effectively isolated from each other by the sea or by humid regions. Certain relationships may be cited between the deserts of North and South America and between those of North and South Africa, at the same time that there are a few slender threads of connection between America and Africa, and between Africa and Australia. Much stronger are the relationships between each of the desert areas and the warm humid regions which are nearest to them. It is clear that the deserts have been populated by races of plants and animals from near at hand, and only to a very slight extent by races from other deserts. In each of these great areas the same conditions have been encountered, and the same problems of adjustment have been met by organisms entering the desert from whatever source. Numerous stocks or races have been involved in the settlement of each great desert area. Numerous types and methods of adjustment to arid conditions have been developed. There is scarcely any warrant for saying that one of these adjustments is better than another, for each of them permits the persistence of the stock by which it has been developed. Doubtless there are many extinct types of adjustment, which failed in the double strug-

gle against other organisms and an adverse environment. An examination of the biota of any one of the great desert areas will disclose that there are very many cases in which the same general type of adjustment has been developed by unrelated stocks. Large roots in which water and food reserves are stored and protected by an extremely distasteful coating are to be found in the American deserts in four widely unrelated families of plants. Indeed, with respect to plants, there are very few structural or functional adjustments to the arid environment which are not known to occur in several families. Particular interest attaches to the parallel lines of development that have taken place in widely distant areas of similar character. The vegetation of South Africa offers many examples of analogy with that of North America, the euphorbias resembling the cacti, Aloe recalling Agave and Sarcocaulon suggesting Fouquieria.

The adjustments of an organism to arid conditions may be obvious or obscure. Few structural features would serve to distinguish the ants or the birds of the moist tropics from those of the desert. Certain beetles and reptiles might be readily recognized as desert forms, while others would not. Among the mammals of the desert it is almost wholly features of behavior rather than of structure that have enabled them to colonize the lands of high temperature and little water Among plants it is easy to detect features of structure which serve to reduce water loss or to provide a reserve of water. There are many other obvious features which enable the plant to take advantage of periods of abundant moisture and to escape the difficulties of maintaining their water solvency during periods of great drought. However, an increasing number of cases is known in which plants exhibit differences in water requirement of which there is no hint in their structure. It appears, therefore, that the sure recognition of a desert organism can be based only on its occurrence in the desert, and that an interpretation of its adjustments can be secured only by investigations of its behavior, life history, structure and physiological characteristics, carried on under natural conditions. Desert work has been done in so few places that we have only superficial knowledge on which to base a comparison of the structural, functional and behavioristic features of the biota of the several desert areas of the world. It is an interesting commentary on the conservatism of science that a score of oceanographic institutions and over two hundred marine and fresh-water laboratories are devoted to the investigation of aquatic life and conditions, while there are only three small laboratories in the entire world in which the scientific problems of the desert are being pursued.

The one aspect in which investigation of desert life has reached a fairly satisfactory stage of advancement is the collecting, classification and naming of its plants and animals Through the assembled results of taxonomic work it is possible to draw several conclusions. The desert has fewer species of plants than the moist regions, about the same number of species of birds and mammals, and a greater number of species of reptiles. The organisms of the desert show varying degrees of relationship to those of moist regions Most of the species, many of the genera and a few of the families are distinctive. These degrees of relationship are unlike in America, Asia, Africa and Australia.

Only through close cooperation between the geologist and the biologist will it be possible to estimate the duration of arid conditions in the several great desert areas and to reconstruct the stages of earth history which have furnished the setting for the development of desert life. Thus only will it be possible to determine whether age, differences in



AN UNDRAINED BASIN IN THE MOHAVE DESERT, CALIFORNIA

ALMOST THE ENTIRE VEGETATION IS HERE FORMED BY ONLY TWO SPECIES OF PLANTS. IN THIS REGION THERE HAVE BEEN PERIODS OF THREE YEARS WITHOUT PRECIPITATION.

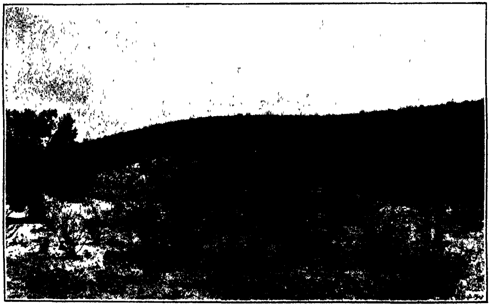
severity of conditions or other factors are responsible for the existence of far more highly specialized types of life in some deserts than in others.

Just as human "history is past politics," so is the history of the desert biota no more than a study of its distribution, the character of its environment and the nature of its responses to the conditions which prevailed at successive periods in the past. The relations that exist to-day, and are now under investigation, have been determined to a great extent by the conditions which existed yesterday and are now subject to investigation only by means which are indirect, inferential and incomplete. Attempts to unravel the problems of origin and history of desert life through faunistic and floristic work on the animals and plants of to-day will make successful progress only when conducted in close conjunction with the facts known in regard to the habitat, behavior and physiological characteristics of the biota, and with the maximum aid from the findings of developmental morphology and comparative anatomy.

Two fundamental questions underlie all inquiries regarding the adjustment of life to desert conditions. How does the organism handle its water, and how do conditions of intense and prolonged illumination affect its life processes? The answers to these questions will have much of common application to plants and animals. However, the plant bids fair to show a higher degree of qualitative adjustment to extreme conditions because of its immobility. The rodents of the desert have acute problems of food supply, but their relatively damp and cool underground homes protect them from extremes. An exposure of fifteen minutes to the midday sun is fatal to many of them. Birds, reptiles, insects and larger mammals are all out of sight at midday in the hot, dry seasons. Meanwhile the perennial plants are exposed to desiccation and illumination and either meet these conditions or perish.

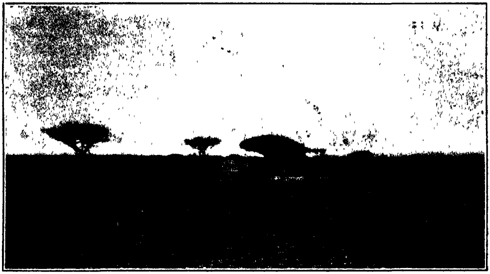
The investigation of water relations has advanced further than that of light relations, because of its greater simplicity and surer physical background. Particularly in the case of plants has there been enough work to give a fair understanding of water loss and the relation of arid conditions to its daily and seasonal fluctuations, and also of water storage and the features of physiological behavior that are associated with it. In the investigation of the soil as a source of water for the plant, the entry of water into the plant, and the movements of water in its stem and other tissues, there is a large unworked field of great importance Relatively little has been done on the water relations of animals A comparison of the rôle of water in metabolism in the animal groups of the desert is not yet possible. The loss and requirement have been investigated in only a few forms. Many desert animals are known to take no liquid water, and our knowledge of their supply through moist or dry food is very incomplete. Terrestrial insects are exposed to higher temperatures than any other animals, but very little is known about their temperature relations and the bearing of these relations on their obviously low water requirement. In the case of both animals and plants it is important that the investigation of the relations of water, light and temperature be conducted in such a manner as to give adequate weight to the fact that these conditions are all operating concurrently and that the three have very close interrelations.

Considerable attention has been given to the obvious and easily studied features of structure which characterize desert plants, particularly those which may be interpreted as having to do with the conservation of water Far more significant than any of these external devices is the ability of certain organisms to withstand the extremes of adverse conditions without possessing any



LOW VOLCANIC HILLS

ON THE WEST COAST OF MEXICO, NEAR PALMA, SONORA. THORNY, SMALL-LEAVED SHRUBS ARE THE PREVAILING PLANTS.



PLAINS NORTHWEST OF SUAKIN,
IN THE NUBIAN DESERT, WITH A VERY OPEN COVER OF THORNY TREES AND SHRUBS PHOTOGRAPH BY D. T. MACDOUGAL.

of the external mechanisms which appear to be so important to certain of the higher plants. Particularly among the mosses and ferns are many cases in which the leaves are able to withstand prolonged desiccation without their protoplasts losing the ability quickly to resume activity when freshly supplied with water. The features of drought resistance may be studied in these plants or in some of the desert insects with bright prospects of fundamental results. The neglect of such problems has been due largely to the fact that the men who have had an opportunity to work in the desert have not been able to remain there for more than a few months. The investigator with limited time selects the problems that will give quick returns rather than the ones that promise fundamental results at the expense of many years of work.

An understanding of life under desert conditions can not be built up by the employment of any one restricted method of procedure. Although the problems involved are not, on the whole, so complicated as those of moist regions, and particularly the moist tropics, they can nevertheless be attacked with profit only by a broad investigative movement. Such an approach requires the employment of methods and outlooks from the entire range of biological science. The view-point of the old-fashioned naturalist is of great importance in studying the life histories and behavior of all groups of animals. The study of distribution must go hand in hand with that of the relation of organisms to environmental conditions. The study of structure must accompany the investigation of function. The study of function must lean heavily on the physical sciences. The solution of the intricate problems of the adjustment of life to desert conditions requires a closely interlocking utilization of the methods of all aspects of biological research.

The essential unity of desert problems has been strongly emphasized by the study of environmental conditions and of plant and animal life which has been

SANDY PLAINS BETWEEN KHARGA AND DAHKLA,

IN THE LIBYAN DESERT, WITH HILLS ERODED BY WIND-BLOWN SAND. HERE, AND IN SIMILAR SITUATIONS IN THE SAHARA, ARABIA AND THE DESERT OF GOBI, PLANT AND ANIMAL LIFE ARE AT THEIR MINIMUM FOR THE LAND SURFACE OF THE EARTH. PHOTOGRAPH BY D. T. MACDOUGAL.

carried on in the southwestern United States during the last 30 years. In many respects the plants are less profoundly influenced by each other than they are in moist regions, and more closely affected by the environment. The interrelations between the life and the environment are intimate and intricate. Every aspect of the desert is closely tied to every other aspect of it. The influences of the climate on physiographic and soil processes, the relation of these to vegetation, the influence of vegetation on the life and fate of animals, the manifold influences of animals upon plants, and the reciprocal effect of plant and animal life on physiography and soils, all combine to form a vast nexus of relationships which no type of investigation dares to disregard The problems of the desert can not be pursued without a wide view and a comprehensive attack. The realization of their unity has been impressed upon the mind of every one who has worked intensively in the arid regions.

The study of the desert and the study of the sea have much in common in the breadth and complexity but essential unity of their problems. There are, nevertheless, some profound differences between the activating philosophy of the oceanographer and the eremologist. The attractions of marine work have recently been set forth by Dr. H. B. Bigelow in his suggestive little book "Oceanography." The morphological diversity of marine life has been its principal attraction, together with the fact that its life processes are carried on under con-

ditions which are vastly more uniform in time and space than those on land. Every reason that Bigelow has adduced for the desirability of studying the life of the ocean constitutes a tacit argument for avoiding the study of terrestrial life. Under uniform conditions of moisture none of the structures or processes are developed which adjust life to meager and uncertain supplies of water. Where uniform conditions of temperature can be secured by movements of a few fathoms per annum there can be found none of the adjustments to temperature extremes which are so important in terrestrial organisms. Many marine animals can be had in great abundance for experimental work and reared successfully under controlled conditions, whereas numerous land animals can be secured in definite stages of development only on the rarest occasions, and can be reared with the greatest difficulty. These facts merely spell our ignorance of the conditions which make the multiplication of organisms more difficult and precarious on land than in the sea. In brief, almost every one of Bigelow's examples of the desirability of marine life for scientific investigation, in behalf of effectiveness, is an eloquent argument for making the study of biology as narrow as possible, since in every case its suitability is founded on the opportunity to escape complicated situations. These complications are precisely the things that make terrestrial life what it is.

The largest problems of the desert, in every field, are those of origin and process This applies to the origin of the land forms and mountain masses and to their determination of the character of the climate. It applies to the processes by which the face of the earth is worked over and remade under the influences of an arid climate. It applies to the origin of soils and to the slow physical, chemical and biological processes by which their development is accomplished. It applies with particular force to the great problems in the origin of plant and animal life and to the processes which make the activities of the desert organism distinctive. To the biologist the essential problem of the desert is the study of life under extreme physical conditions, of the events by which the biota of the desert have entered it, the developments by which their entry was accompanied, and the structural and functional features by which they are able to maintain themselves in it.

There can be no question as to the fruitfulness of the investigation of the biological phenomena which take place under extreme conditions Furthermore, it is notably true of the desert that its problems are sharply defined, by reason of the vigor of the environment and the simplicity of the flora and fauna. The broadened conceptions and better balanced views that are contributed to biology by the study of desert origins and processes are an important part of the progress of science. The fact that one fourth of the earth's land surface and nearly one fourth of the area of continental United States is arid or semi-arid gives added weight to the importance of a deeper knowledge of these great areas.

RACING CAPACITY IN THE THOROUGHBRED HORSE

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PART I. THE MEASURE OF RACING CAPACITY

THE SOLUTION OF THE SPECIFIC PROBLEMS INVOLVED IN THE INVENTION OF A MATHEMATICAL YARD-STICK FOR RACING CAPACITY

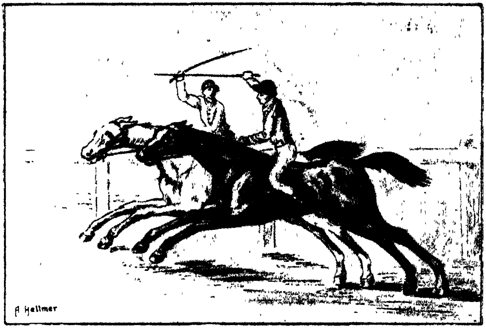
THE purpose of the research reported in these two papers is to find the laws by which Nature governs the transmission of inborn racing capacity from one generation of Thoroughbred horses to another. These investigations, which began in 1923, were made possible by the support of Walter J. Salmon, Esq., distinguished breeder of the Thoroughbred horse, and by the scientific direction of the Carnegie Institution of Washington. Mr. Salmon's extensive breeding farm, Mereworth Stud, at Lexington, Kentucky, has been the field experiment station for this work; while the laboratory researches have been conducted by the Carnegie Institution of Washington in its Department of Genetics at Cold Spring Harbor, Long Island, New York.

In the Salmon library at Cold Spring Harbor there has been built up "a very substantial body of working data" for research in the genetics of the Thoroughbred horse. This library has assembled the principal racing and breeding records of all countries, and the most important books and papers by investigators and breeders of the Thoroughbred horse, published during the last 200 years, principally in England, America, France and Germany.

The laboratory has systematized carefully the first-hand breeding and racing records of some 10,000 Thoroughbred horses, about one half fillies and one half colts and geldings, mostly in the United States, England and France with a few hundred scattered in other countries. These records were organized primarily for analysis to attack the main problem, that is, as above stated, to discover the mathematical rules by which Nature transmits racing capacity from one generation of Thoroughbred horses to another.

Before we can successfully attack the genetics of any quality we must understand its essential nature as a structural or physiological entity, whichever it may be, in the individual. The quality must be defined exactly so that throughout the studies we will be measuring and analyzing and talking about the same thing. By definition "racing capacity in the Thoroughbred horse is that physiological entity which enables the horse in running races to carry great weights, for long distances, at high speed—sex and age being duly considered and other factors being constant." The thing is racing capacity—the inborn ability as distinguished from ability added to or subtracted from inborn quality by training or by other environmental influences. Racing capacity thus depends basically upon heredity. In the measure of inborn racing capacity differential environmental influence must, of course, be reduced to a minimum; but at least all influencing conditions, whether inborn or environmental, except the one being measured must be kept as constant as possible for the particular investigation.

In possession of a satisfactory definition of racing capacity, it is next necessary to examine this quality critically,



MATCH BETWEEN GIMCRACK AND BAY MALTON, 1769

FROM CONTEMPORARY PAINTING BY BEST

The above painting shows the contemporary Thoroughbred idealized in both conformation and action. It shows also the size of jockey and the style of riding in running races in fashion prior to a generation ago when Tod Sloan introduced the now universal and faster "monkey seat" shown in Figure 3, and in the picture of Display ridden by jockey Maiben.

The Thoroughbred, or running horse, was developed in Great Britain from "Arabian, Turk and Barb" stallions, and light native British mares, during the last three centuries. While beginning shortly after the destruction of the Spanish Armada in 1588, there were a few random importations, it was really during the reign of Charles II, 1660–1685, that the importation of superior desert-bred saddle stallions laid the foundation for the Thoroughbred horse. Many centuries of severe selection had developed, in the desert countries of the Mohammedan world, a saddle horse *par excellence* in transportation, in herding, and in war. These desert stallions were brought to Great Britain and crossed with the racing type of native British mare, and thus the Thoroughbred or running horse had its origin.

To name the greatest of these imported foundation stallions, we must list the Beyerley Turk 1689, the Godolphin Barb 1730, and the Darley Arabian 1710. Each gave rise to a famous line, the descendants of which have long since been inter-crossed. The Darley Arabian was the great-great-grandsire of Eclipse (foaled during the eclipse of 1764). As a race horse Eclipse was unbeaten, and he is also the most important foundation sire of Thoroughbreds. He himself sired 334 winners of races.

For many generations the desert-bred Arabian horse was admitted without further credentials to the Thoroughbred stud-book. But now even such entry is closed, and no horse may be registered as a Thoroughbred unless both his sire and dam are also registered in the Thoroughbred stud-book.

From Great Britain the Thoroughbred has spread over the entire world, and in turn has contributed foundation stock to nearly all of the best breeds of the world's horses which require speed and stamina. About 15,000 Thoroughbred foals are now produced the world over each year. The United States, Great Britain, France, Argentina, Australia and Germany lead in the number of foals produced annually by this breed, but nearly all countries are represented to some extent. In racing capacity Great Britain probably still produces the best foals, but the United States is rapidly overtaking her.

particularly in its anatomical, physiological and developmental aspects We must be able "to diagnose" it when we find it in an individual, but above all we must be able to measure this thing—the inborn physiological entity called racing capacity—with considerable accuracy.

The Yard-Stick for Racing Capacity

The elementary things in racing capacity are sex, age, weight-carried on the back, distance-run and speed attained For the measure of racing capacity it is obvious that no existing yard-stick will suffice. It is necessary then to invent a new standard measure. This task can be attacked hopefully because most of the basic measures which enter into racing capacity have long ago been perfected

The successful yard-stick for racing capacity as a physiological entity must enable one to answer the question, "Just how good a horse was 'Sir James,' judged solely by his racing performance?" It is obvious that the perfected yard-stick must measure racing capacity as shown by actual performance in each different race; that is, it must measure quality of performance on a definite mathematical scale.

Yard-sticks for distance, for weight, for age and for speed have, through the centuries, been finally perfected so that now they are very exact. Each, with its minute subdivisions, has been in use for a long time as one of the essential tools in commercial transactions, in biology and in physics. For measuring age we have the measuring stick of the year, which is quite accurate; for weight-carried on the back of the running horse we have the measure in pounds; for distance-run we have the exact measure in furlongs; for speed attained we have the very accurate yard-stick of minutes and seconds. The new measure now needed must provide the correct inter-compensation for sex, age, weight-carried, distance-run and speed attained in races truly run on good or fast tracks, all other factors being constant.

One sees immediately the practical nature of the problem. Increased weight-carried on the back and increased distance-run, each, slows down the horse; then, "How many pounds are equivalent to one furlong in slowing down the horse?" It is clear that this inter-compensation depends upon all other essential measured factors—age, sex, the magnitude of distance and the magnitude of weight with which we are dealing.

The correct formula for the measure of racing capacity must provide this inter-compensation. Each actual race which the horse runs must be measured by a definite figure called the Quality of Performance. Such a figure is a piece of evidence concerning the racing capacity of the horse. All such pieces of evidence must be properly coördinated and correctly stressed in order to determine just how good a race-horse the particular individual is; that is, what his Biological Handicap is

The thing which these studies are trying to measure is, then, the inherent racing capacity of horse-flesh, which, under a given set of conditions of sex, age, weight, distance and speed, can be reduced to a definite figure. It is not sufficient to depend upon adjectives such as "very poor," "poor," "medium," "fine" and "superior." Definite mathematical yard-sticks in studies of this sort must supplant adjectives.

Major Factors

What does each of these several major factors, all other factors being equal, do to speed? It is necessary to go about this inquiry systematically.

1. Distance Run: In this particular phase of the main problem, it is necessary to take the best records which

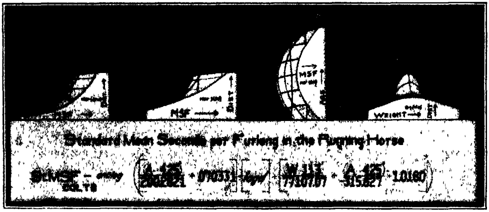


FIG 1 BASIC FORMULA FOR THE MEASURE OF RACING CAPACITY IN THE THOROUGHBRED HORSE

ST M.S F. FOR COLTS THE FORMULA AND ITS CONSTITUENT MATHEMATICAL MODELS.

In this formula there are four variables, namely, St.M.S.F., or time; A, or age in years; d, or distance run in furlongs, and W, or weight-carried on the back, in pounds. For model-making of this sort one dimension is needed for each variable factor. Because we have only three dimensions available for model-making, one mathematical model will not suffice for the whole present formula with its four variables Instead of one model for the whole formula, we must therefore build four types of models as pictured; and an indefinitely large series would be necessary to represent the whole range of the fourth variable for each of the four model-types.

The first model pictured makes age constant at 4.25 years, and makes mean-seconds-per-furlong for speed, furlongs for distance, and pounds-on the-back for weight, the other three dimensions. Similarly, for model two derived from this same formula, we make weight constant at 113 pounds, and therefore have the whole range of variability for each of the other three factors. In the third model, distance-run is made constant at 8 furlongs, with the other three factors variable. In the fourth model speed, or rather its correlative, time-consumed, is made constant at 12.722 mean-seconds-per-furlong, while the other three factors are given their whole range of variability.

Thus we appreciate what adding one extra factor or dimension does to complicate curve-plotting and model-making, but also how much extension and flexibility it gives to usefulness of the formula.

Practically this formula is worked out only once for each combination of A, d, and W, and the results, in terms of St.M.S.F., are entered into permanent handy reference tables. These tables are used as follows: We have, for example, in the American Oaks, run at Belmont Park in June, 1930, for a stake of $19,600, the winning filly Snowflake, 3 25 years old, who, carrying 121 pounds, ran this truly-run 11-furlong race, with 9 horses starting, on a fast track, in 2 minutes 18⅖ seconds, or in 12.582 mean-seconds-per-furlong. Now by referring to the tables which give the values of the above formula, we locate the set-up of sex, age, weight-carried, distance-run, and speed, as above stated. We thus find the standard (or the mathematically smoothed best speed of the breed) for the particular set-up to be St.M.S F. = 12.630. Thus, dividing 12 630 by 12 582, we conclude that the quality of performance of the filly Snowflake in this particular race was 1.0038. Thus each actual race becomes a piece of evidence for computing racing capacity in the individual horse.

Consider further (Fig 3) the Futurity. We find that Bubbling Over, second in the race and carrying 122 pounds, is credited with the top Q.P. of 9675, while the winner, with 117 pounds, is credited with a Q.P. of .9649. In sex-adjustment, again in the Futurity, note that the filly Edith Cavell, carrying 116 pounds and consuming 102.3 seconds in running the mile, is credited with a Q.P. of .9597, while Dress Parade, a colt carrying 119 pounds, consumed .3 of a second less in running the mile, but is credited with a Q.P. of only .9544. This illustrates the adjustment of the sex-difference by the standards required for colts and fillies. Geldings have still a third standard.

American Thoroughbred horse-flesh have made for each distance; but there are a great many sets of conditioning factors. Thus the relation between speed and distance had to be plotted for each possible different combination of sex, age and weight-carried—all other factors such as track-condition and the trueness of the running being equal. The analysis of many hundreds of records shows that if we increase the distance-run, we slow down the average speed per furlong very rapidly at first, but, in the longer distances, for instance between 12 and 16 furlongs, an increased distance of a furlong or so still slows down the horse, but the amount slowed down for each furlong added decreases rapidly. It is within the range of actual racing—3½ to 12 furlongs—where added distance counts most heavily. Races naturally fall into the classes of sprints and distance races. In a sprint, there must be no conservation of energy, but the highest possible speed must be maintained from start to finish. Depending on the horse, a sprint ranges from approximately 2 to 7 furlongs. But, for a longer race, the highest average speed is attained by conserving energy, that is, by "rating the horse along" in the earlier stages of the race, then, in the later stages, urging him forward so that when the race is finished the horse is "ridden out," and he has maintained a practically uniform speed throughout the course.

A. E. Kennelly long ago proved this latter principle true in all athletic record-making, whether by man swimming or running, or by the horse trotting, or in any other speed-contest by animals. Relative uniformity of speed throughout the race is an essential characteristic of each endurance speed-contest of whatsoever kind which establishes a record.

2. *Weight Carried:* In weight-carrying capacity a similar set of individual studies had to be made. It was necessary to determine what weight-carried does to speed, for each condition—complex of sex, age and distance-run—all other factors being constant. These studies in weight-carrying capacity have discovered an interesting phenomenon. Let us call it the "switch-back effect." We all agree that if you put great weight on a horse it will slow him down. It is also assumed that the more weight you can take off a horse's back the faster you can make him run. But the analysis shows that there is a limit to this increase of speed by taking weight off. Whether it is because small jockeys are poorer riders on the average, or whether the horse needs a ballast, is not important here, but the fact is undoubted in the analysis of racing records. In engineering and in physiology we find many parallels to the "limits of a good thing." The kick of the gastrocnemius muscle of the frog in lifting a weight under electric stimulation, and, in artillery practise, the relation between the weight of the powder-charge and the distance which a shell of the same weight will go, are examples of "the limit of increasing and the beginning of decreasing effect by increasing cause."

3. *Age:* Here again it is necessary to plot many curves, each showing the best speed-records which American Thoroughbreds have made for each age. Each curve is based upon its own complex of sex, distance-run and weight-carried. Judged by every factor except age, fillies improve in absolute capacity until about 2½ years old, then gradually old age sets in and absolute capacity declines. Colts improve up to 3½ to 4½ years old, then decline; while, as a rule, geldings improve until they are about 5½ years old, then decline slowly due to old age. While most Thoroughbreds are foaled in early spring, all ages of the Thoroughbred are judged from the previous January first. Thus, in the northern temperate zone, it is seasons rather than the exact number of months and

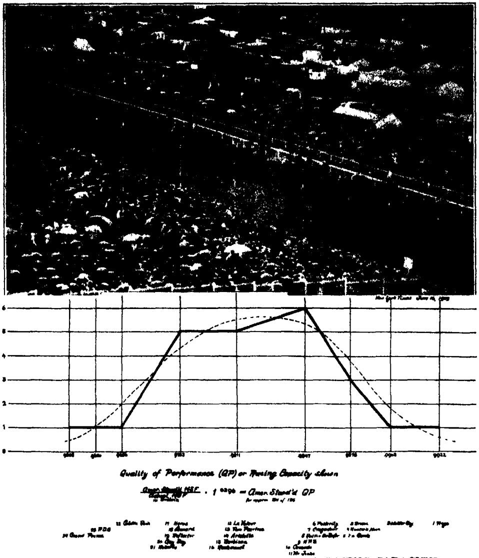


FIG. 2. A NORMAL DISTRIBUTION CURVE OF RACING CAPACITY

SHOWING THE FIELD OF 24 HORSES "NEARING THE LINE" IN THE DERBY STAKES AT EPSOM DOWNS, JUNE 5, 1929. DISTANCE: 12 FURLONGS; AGE: 3 YEARS, SEX: COLTS; WEIGHT CARRIED: 126 LBS. FILLIES ARE ELIGIBLE, BUT NONE STARTED IN 1929.

In such a set-up the starters are not expected to come out even at the finish, but, by frequency and racing-capacity, to be distributed along a normal probability curve. This picture shows the outcome of test-performances in a very complex physiological activity with almost the mathematical accuracy expected in a series of experiments in physics. With this set-up it is expected that one outstanding horse will lead; then will follow a few competitors for place; then, in the middle there will be found the great mass of entrants; then a little farther back the group will thin out, and finally will be closed by one or two trailers.

days which count most in maturing and aging the running horse.

The "switch-back effect" which was observed in weight-carrying capacity is also apparent in age. Horses improve in absolute racing ability until a certain age, then decline. Thus there must be two ages for a given racing ability in the same horse; once on the uphill of age and once on the downhill. To illustrate this principle in reference to age, it is noted that, for example, when the weight-carried is about 113 pounds, the distance-run is a sprint of about 3½ furlongs, the sex under consideration being colts, the age-range being that of practical racing and all other factors being equal, the "generally declining" older horse can, at one definite age, run as fast as he could at another definite age in his "generally improving" ability as a young horse. This seems paradoxical, but it is true.

4. Sex: Sex is, of course, a major element in racing capacity. Since sex-difference can not be measured as such by figures on a yard-stick, it is necessary to invent racing-capacity yard-sticks independently for colts, for fillies and for geldings. If racing differences in the sexes were measurable by a yard-stick, we could add the sex-factor mathematically to the formula, and thus have one formula instead of three for the yard-stick for racing capacity. But until the physiologists learn how to make such a yard-stick for sex we must continue to use the three formulae.

However, the difficulty is gotten around practically by designing the measuring stick for racing capacity for each sex as a standard ratio. In each case this standard is the "mathematically smoothed best," that is, the highest speed which "Thoroughbred horse-flesh" has thus far achieved for the particular complex of major factors, and the quality of performance of the particular horse in a race under the particular set of conditions is the ratio of the standard time for the breed to the time actually made by the individual. Thus racing capacity is made mathematically comparable in different individual horses regardless of sex, or rather with sex duly considered.

Other Factors: Others factors enter Having learned essentially how these different major elements of sex, age, weight and distance inter-compensate each other in relation to speed, it is possible to apply the resulting formula to determine the Quality of Performance in an absolute figure for any race-performance of an individual horse truly run on a good or fast track.

In the running horse the "riding sense" or ability of the jockey comes in as a major factor. This is one additional reason why, in computing racing capacity, it is necessary to select the horse's best races. Many things can cause a horse to run slower than capacity, but nothing can make him exceed capacity.

For the time being studies will be confined to American dirt tracks, some a little faster than others The track factor in America is simpler than that in Europe. It is true that American tracks differ in fastness, but they are all dirt rather than turf tracks, and in general the American dirt tracks are about three per cent. faster than the turf tracks of Europe. The present studies are thus confined to American dirt tracks in good or fast condition. Records of track condition are, of course, kept, whether "fast, sloppy, heavy" or the like, for the purpose later of analyzing mud-running capacities in mathematical fashion. But mud-running is not yet inter-compensated by a mathematical yard-stick, although the possibility of such inter-compensation is promising.

Inter-compensation of Factors

With an eye single to finding the correct formula for Quality of Performance these curves are systematized by fami-

FIG 3. AN AMERICAN HANDICAP RACE

ADMITTING BOTH COLTS AND FILLIES AND ASSIGNING EACH STARTER A WEIGHT-TO-BE-CARRIED DESIGNED TO EQUALIZE CHANCE-TO-WIN.

PIMLICO FUTURITY, November 6, 1925, Purse, $40,000. For Two year-olds Distance: 8 furlongs; Track condition: fast. At the finish the order was:

Place	Name	Sex	Weight Pounds	Time in Seconds	Quality of Performance
1.	CANTER	Colt	117	100.8	.9649
2.	BUBBLING OVER	"	122	100.8 +	.9675
3.	DISPLAY	"	119	101.1	.9629
4.	PENSTICK	"	119	101.3	9610
5.	CRUSADER	"	117	101.4	.9589
6	ESPINO	"	119	101.6	.9582
7.	MARS	"	119	101.8	.9563
8.	DRESS PARADE	"	119	102.0	.9544
9.	EDITH CAVELL	Filly	116	102 3	9597
10.	ACROSTIC	Colt	119	102.4	.9507
11.	LANCASTER	"	117	103.2	.9425
12.	FLIGHT OF TIME	"	119	103.4	.9414
13.	MARYGRACE	Filly	119	105.0	.9365
14.	PRINCE OF WALES	Colt	119	105.2	.9254

Unlike the Derby (Fig. 2) the Pimlico Futurity (Fig. 3) is a handicap race; that is, in the Futurity each entrant is assigned a certain weight-to-be-carried in pounds, which, in the judgment of the handicapper, will give the particular horse an even chance-to-win. This picture shows the leading three, not at the finish of this 8-furloug race, but at about that point where "distance begins to tell." Those horses in better condition for the particular race, and possessing better inborn distance-going capacity, show their respective merits from this point on. It is noted that the best quality of performance was not made by Canter, the winner of this race, but by Bubbling Over, who lost the race of one mile "by a nose"—too small a fraction of a second for any hand-operated stop watch to detect; but that Bubbling Over carried five pounds more than the winner.

lies; they are cross-sectioned with a minimum of "strait jacketing" to iron out their discrepancies. We have thus a set of standards for any complex of sex, age, weight-carried and distance. These standards state the "smoothed best" which the breed has accomplished up to the present time. How good a particular race-performance is, or how good a race-horse a particular individual is, depends upon its actual performance when we consider sex, age, weight-carried and distance-run, compared with the best which the breed has done under the same complex of conditions.

For colts these basic factors—age, weight-carried, and distance-run—are shown by the mathematical models (Fig 1). These models represent both a smoothing of the actual record-making data and a plotting of the formula which these data gave Each model shows the best "par value" which horse-flesh has achieved up to the present time under the given set of conditions Of course the smoothed records up to any date other than the present would have been theoretically possible, but the records are now exceedingly numerous and exact, and the present proved to be a very appropriate time for standard-making These present standards may be used no matter how much advance in racing capacity or how much degeneration may take place in the future. The standards represent a par value, and we can measure both above and below them.

After all mathematical cross-sectionings and smoothings are finished, the general formula (Fig. 1) was again applied to the basic data, and exceptionally close-fitting curves were found. This supplied the common sense—it gave confidence that the general formula for Quality of Performance is correct. In building the mathematical models for quality of performance it is necessary to use four sets or families of models for each sex instead of one single model, because there are four major factors, distance-run, weight-carried, age and speed, and nature supplies only three dimensions for mathematical models of the sort here needed. Consequently, to show all types of inter-compensation of these four elements requires four mathematical models taking three dimensions at a time. There are, of course, in Nature, as many "dimensions" as there are factors in a formula of this sort. Mathematically, in this formula there are four dimensions. We can get the surface for any one of the four mathematical models by substituting in the formula a definite value for the one missing factor or dimension. For instance, Model 1 (Fig. 1) gives all the curves of the standard mean seconds per furlong for all conditions except age, consequently a similar form like this one must be built for every age of the racing horse. Model 2 gives all standards except for weight, consequently a form similar to this one must be built for each weight. Model 3 gives all standards except for distance, consequently a surface of this sort must be found for every distance for which we may desire a standard Model 4 inter-compensates distance, weight and age for a definite speed, namely, 12 722 mean seconds per furlong; consequently a family of forms like this one—one for each speed in which we are interested—must be worked out.

At this point attention should be called to the fact that while two horses may have the same final rating in racing capacity, one horse may be a splendid weight-carrier but a poor distance-running horse, another may pile up capacity-credits on account of coming-to-hand especially early, or maintaining high racing capacity late in old age. Thus any combination of the basic qualities, each properly stressed or weighted, goes into the final figure for racing capacity as a whole. This opens an important side-field for the still more refined ge-

netic analysis. It is the measure and inheritance of the special capacities constituent to racing capacity as an inter-compensated whole. The most important of these highly specialized capacities are distance-going capacity, weight-carrying capacity, age capacity, and mud-running capacity. In researches on each of these we desire to keep all other factors constant. And so in almost any physiological complex there is no end of unit-making, of analysis-overlapping and of inter-compensations—both structurally and physiologically in the individual and in genetic origins

Quality of Performance: The Mathematical Formula

The formula (Fig. 1) accomplishes all these tasks of inter-compensation. It supplies all of the standards which are needed for judging the quality of performance of any colt under any set of conditions of age, weight-carried and distance-run, other factors being constant But, as previously stated, a set of curves and formulae—independent but of parallel type—have been worked out for each sex.

For each set of conditions the standard represents the quality of performance at par, or $QP = 1.000$. Thus, if a horse under a given set of conditions makes the mean seconds per furlong given in the standard for this set, his quality of performance is 1.000. If, in a truly run race on a good or fast track, his mean seconds per furlong is less than the standard, then his quality of performance is more than 1.000. If he requires more time than called for by the standard, then his quality of performance is less than 1.000.

The formula then reads as follows:

Quality of Performance

$$\text{Q.P.} = \frac{\text{Standard Mean Seconds per Furlong.}}{\text{Actual Mean Seconds per Furlong.}}$$

When we compare two excellent performances in either the same or in different races, we immediately ask: Which horse ran the better race? The thing can be argued back and forth without decision, unless we have definite standards of measurement. But with such yard-sticks we can answer it definitely, if we agree that the races were equally well ridden and truly run and that the tracks were equally fast. We know the sex and age, and it is necessary then only to determine mathematically the way "horse-flesh" inter-compensates weight-carried, distance-run and speed for the particular physiological and environmental set-up.

Another question often arises, "Why, if Man o'War was the best horse which America ever produced, did he not win all of his races?" It must be recalled that quality of performance which a horse shows in a given race is a very delicately balanced affair. In order to deliver his maximum capacity the horse must be in prime condition, he must be well ridden, the race must be truly run, and many other factors must be favorable.

Moreover, if the particular performance is made in a "handicap race," different horses carry different weights. These weights are assigned by the handicapper in a manner which he believes will give each horse, on the basis of his "past performance," an even chance to win. If such handicapping were an exact science, and the "quality of performance" of the individual horse were never variable, then all horses in the particular handicap race would cross the finishing line at the same instant. But, as a matter of fact, actual quality of performance is subject to great variability. This is an important factor which must be considered in the measure of racing capacity. Some horses show little range in quality in their successive best races; they are "reliable." Others are erratic, sometimes running very superior races, while at other times they are disappointing. It is, therefore, necessary in judg-

ing the racing capacity of the horse to take "only but all" of his best races into consideration.

It is this variability in quality of performance that makes racing so enticing as a sport, and also which makes it interesting and important to science. Both in the keen judgment of "racing men" and in sound scientific computation, the mathematical picture of a selected "horse-race" is painted with the brush of odds or probability, and not with the finger of certainty In fact, many of the former cocksure formulae of so fundamental a science as physics are now being stated in terms of probability. Of course when we compare the subject-matter of physics with the subject-matter of biology, generally but not always, the highest class-probability predicted in a physical matter much more nearly approaches certainty than does such probability when it involves a complex biological element

Racing Capacity or Biological Handicap: The Mathematical Formula

In order to distinguish between quality of performance which applies to the single race, and Racing Capacity which applies to the whole racing career of the horse as a measure of his "inborn racing qualities," the measure of the individual's racing capacity for his whole career is called his "biological handicap," or his "B.H" All of the actual races run by the individual horse must be taken into consideration in order to answer the question, "Just how good a racehorse was 'High Spirit'?" *i.e.*, "What was his racing capacity, that is, his biological handicap?" While every race is a piece of constituent evidence, it is found that the real capacity of the horse is better measured by taking the best of his races, in accordance with definite principles of selection. The number of races selected, as standardized by the present study, depend upon the total number run and varies from 1 to 10 as follows:

Number of races, truly run and well ridden on good or fast track, selected for determining racing capacity or B.H.:

Number run	1	2	3	4	5	6	7	8	9
Take best	1	1	2	3	4	5	5	6	6

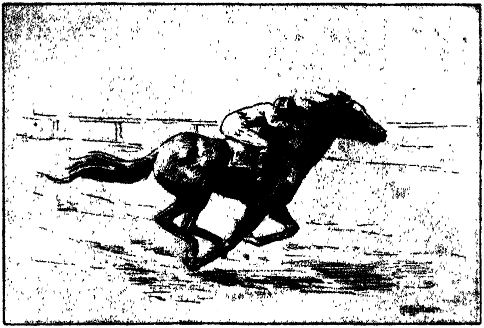
10	11	12	13	14	15	16	17	18	19	20	20+
7	7	7	8	8	8	9	9	9	9	10	10

Now, if we take the mean Quality of Performance of these best races, we get a good picture of the racing capacity of the horse, particularly if he has run a large number of races. Any horse which competes in 6 or 7 races, truly run on good or fast tracks, under varying conditions of age, distance-run and weight-carried, supplies data for a good mathematical picture of his real capacity.

But men who handle horses do not use the term "par value" and "racing capacity"; they say, "This is a 110-pound horse," and "That is a 120-pound horse," not meaning, of course, that he always carries so many pounds, but that that is "how good a horse he is." It is another technical use for the word "pound," which, depending on the context, might be avoirdupois, English money, or racing capacity. Now it is found useful to transform mean quality of performance into pounds, or biological handicap, and the following formula does the task very well:

$$\text{Biological Handicap (B.H.)} = (716\ \overline{QP}) - 585.$$

Final B.H. is computed when the racing career is finished. B.H. computed at any earlier date is tentative (BH_t), and is based on performance to the particular date. It makes no difference in subsequent mathematical calculations whether this straight line transformation is used to turn mean quality of performance into biological handicap, or



ETCHED FROM AN ACTUAL PHOTOGRAPH.

DISPLAY, BAY COLT 1923, BY FAIR PLAY OUT OF CICUTA,

WINNING THE HAWTHORNE GOLD CUP, OCT 11, 1928 DISTANCE RUN—10 FURLONGS WEIGHT CARRIED—126 POUNDS. AGE 5.75 YEARS RACE TRULY RUN NINE STARTERS. FAST DIRT TRACK TIME 2·03. THESE CONDITIONS WORK OUT MATHEMATICALLY FOR DISPLAY IN A QUALITY OF PERFORMANCE—1.0019. DISPLAY RACED IN HIS 2, 3, 4, 5 AND 6 YEAR-OLD FORMS, RUNNING 96 RACES IN ALL, OF WHICH HE WON 23 RACES AND WAS SECOND 23 TIMES. HIS RACING CAPACITY IS RATED AT 130.93. HE WAS BRED AND RACED BY WALTER J SALMON, ESQ., IN THE COURSE OF THE EXPERIMENTS REPORTED IN THESE PAPERS

mean quality of performance is used directly. In either case it measures quite accurately the same "inborn stuff," on the yard-stick of "horse-flesh standards for running at high speed"—sex, age, weight-carried and distance-run being duly considered.

THE PRINCIPLE OF ADDED FUNCTIONS: A USEFUL TOOL IN YARD-STICK INVENTION

Each basic research should yield a useful new tool. In constructing the formula for the standards mean seconds per furlong, the principle of added functions has been developed. Statistical analysis of problems which involve several simultaneous and interacting factors need such a tool.

When it is desired to measure, as a single entity, a complex quality composed in turn of several relatively simple elements, different methods have been tried. The method of index-making is common in the commercial world. In statistical studies multiple correlation has been developed. Each has its uses and limitations. In problems of the sort presented by the physiological nature of racing capacity the method of added functions as here developed is most useful; it has flexibility and it is thus close-fitting to the observed data.

The formula for the measure of racing

capacity is a specialized use of the principle of added functions. Its technique can be used in measuring as an entity any quality, whether a natural physical or physiological entity, a "syndrome," or an arbitrary collection of elementary units brought together through a "chain of connecting functions," provided each constituent element is, in turn, already measurable directly on its own independent basis.

In the theory of functions this work demonstrates the principle which may be stated as follows. If two things (for example, distance and weight) are each independent functions of the same third thing (for example, speed), then these first two things (distance and weight) are, for each specific value of this third thing (that is, speed) unique functions of each other. The principle of added functions, by the mathematical models shown in Fig. 1, illustrates this very fundamental principle quite clearly.

In heredity Nature seems to function through many somatically independent forces tied together in pairs by their commonness as functions each of the same third factor. This tying together, through a third element, of two apparently independent factors seems to be a basic characteristic of the working of Nature, if indeed it is not the main structure of Nature itself.

Conclusion

By means of the definite yard-stick here developed we can now, with a single figure for each, answer such questions as "Just how good a race horse was the colt Man o'War?" and "Just how good a race horse was the filly Snowflake?" We know that Man o'War was a chestnut colt, by Fair Play, out of Mahubah by Rock Sand, that he raced in his 2- and 3-year-old forms, that in all he ran 21 races carrying from 115 to 130 pounds, for distances from 5 to 13 furlongs, that he won 20 of these races and was second in the one race which he lost, that he "crossed par" 9 times, and that he established many records We know that Snowflake was a chestnut filly, by Mad Hatter, out of Snowdrop by Cicero, that she raced in her 2-, 3- and 4-year-old forms, that she ran in all 30 races, carrying from 103 to 126 pounds, for distances ranging from 4½ to 11 furlongs, that she won 7 races, was second once, and that she "crossed par" 3 times. We also know the sex, age, weight-carried, distance-run, speed (mean seconds per furlong), track condition and "trueness of the race" for each of these individual performances. Although these two horses are of different sex, and never ran at exactly the same age, for the same distance, carrying the same weight, the new yard-stick for measuring the inborn racing capacity of the Thoroughbred horse rates, on the same scale, Man o'War at 139.25 and Snowflake at 127.31.

If we were studying a quality like stature in man this preliminary invention of the yard-stick would be unnecessary, because the foot-rule and the meter-stick have long since been standardized. In mathematical genetics, the study of variable qualities, whether structural or functional, demands first of all a good yard-stick, even if it has to be developed or invented for the specific purpose The two conditions necessary for genetical analysis of the type herein reported are, first, measurableness of the subject-quality in the individual—with the yard-stick in hand, and second, some indication that the particular quality thus measured tends in some manner to "run-in-the-family."

We are now in possession of a reliable yard-stick for the measure of racing capacity in the Thoroughbred horse. We are, therefore, now ready for the next stage of these researches which will seek the mathematical rules by which nature governs the inheritance of racing capacity.

(To be concluded)

THE CONQUEST OF MALARIA: ITS NATURE AND SOCIAL SIGNIFICANCE

By Dr. ARTHUR L. BEELEY
PROFESSOR OF SOCIOLOGY, UNIVERSITY OF UTAH

So vital is the rôle of disease and death in human affairs that the Gibbon of the future will, no doubt, explain the rise and fall of civilizations less in terms of political and social economy and more in terms of disease and sanitation. Such a bio-social interpretation of human history is well-nigh inescapable when we consider for a moment the number and variety of pestilences that from time immemorial have afflicted the race.

When events are viewed in this light their meaning is often quite different from that which tradition assigns them. For example, it is becoming more and more apparent that the American success at Panama was not primarily an engineering feat, great as that was, but rather a sanitary triumph over two of the oldest and most pernicious human maladies—yellow fever and malaria

The occasion for this review of the developments that have led up to the potential—though not the actual—conquest of malaria, is the recent death of Sir Ronald Ross, whose brilliant discovery in India a generation ago added the last link to a chain of scientific knowledge by means of which it is now possible to eradicate this disease completely. The significance of this new knowledge is apparent at once when it is seen that, even to-day, malaria still exacts an annual death-toll of approximately twenty-five million persons in various parts of the world.

Past and Present Theories of Malaria

Because the symptoms of a malarial attack are so distinctive, there seems to be no difficulty in tracing the disease back as far as 1,000 B. C, according to Singer's "Short History of Medicine." Hippocrates refers to the disease and Galen describes it in some detail Herodotus tells how the Egyptians who inhabited the marshes of the Nile were plagued with gnats, and how they wrapped themselves up in nets at night.

Some writers contend that malaria was a contributory cause of the decay of Greek and Roman civilization. But however conjectural this may be, it is a fact, nevertheless, that the mythologies of these cultures contain explicit allusions to the disease. Apollo, the sun god, for example, was worshiped, *inter alia*, for his reputed power to drive away the malaria mists. The healing rays of the sun were thought to be his arrows.

While the pre-scientific theories of malaria have now been completely exploded, the term itself, derived from the Italian *mala aria*, meaning bad air, is still used to designate that class of intermittent and remittent fevers (sometimes called ague, marsh fever, hill fever, paludism, etc.) in which the infection is spread from one person to another by means of a mosquito.

The present scientific explanation of malaria can be epitomized by saying that whenever a female mosquito of the genus Anopheles feeds on a human being with malaria parasites in his blood, the parasites thus extracted undergo development in the insect's stomach. After two or three weeks the mosquito becomes infective, and when, in this state, it bites another human being, it injects into him certain developmental forms of the parasite which are now present in its salivary glands. These minute para-

sites enter the red cells of human blood, multiply rapidly and give off a poison which produces the characteristic fever known as malaria. In a day or two this poison may be eliminated from the patient's system, in which case the fever will subside, but soon another generation of parasites comes to maturity and the patient experiences a recurrent attack. Unless properly treated with quinine these recurrent attacks tend to continue, often resulting, directly or indirectly, in death.

The successive steps which led up to this knowledge constitute an inspiring chapter in the history of human progress.

The Discovery of Quinine

The first great landmark in the conquest of malaria was the discovery of quinine in the seventeenth century.

Quinine is the most important alkaloid obtained from cinchona bark Its chief value, says the pharmacologist, is its effectiveness as an antipyretic or fever-reducing agent. It is a specific antidote for and a general prophylactic against malaria.

The word itself contains the clue to the interesting history of this drug, for *quina* is the Peruvian word for bark. It seems to be well authenticated that this bark was officially named Cinchona Bark by Linnaeus in 1742, in honor of Countess d'El Chinchona who was chiefly responsible for its introduction into Europe. While in Peru she had been cured of an attack of malaria by the use of this tree-bark, a remedy well known to the Indians of that region. The benefits were so striking that the Countess took some of the bark back to Spain with her in 1640.

It seems not too much to say that no drug has proved a greater boon to mankind than quinine. Its extensive use throughout the world, especially during the past fifty years, has materially reduced the ravages of malaria.

Finding the Malaria Parasite in Human Blood

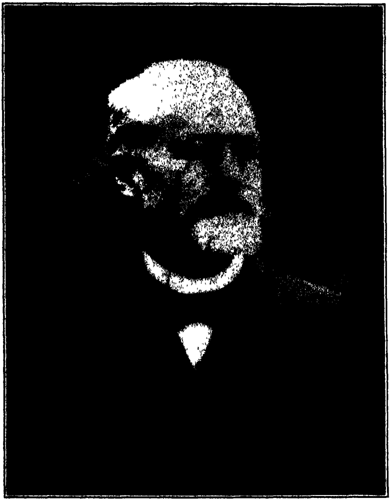
The use of quinine, however, gave no clue as to the cause of the disease for which it has proved to be so effective a cure. It was not, in fact, until something over two hundred years after quinine had been introduced into Europe that the immediate cause of malaria was definitely established

With the improvement of the microscope in the nineteenth century, and the scientific study of human pathology which that instrument promoted, it was inevitable that medical men would, sooner or later, examine the body fluids —especially the blood—for clues as to the possible cause of disease. In the case of malaria, such microscopic work soon established the fact that the blood of a malaria patient contains granules of pigment, a substance then thought to be due to the chemical action of "bad air" on the red blood cells. It was not difficult to see, therefore, why Professor Alphonse Laveran, possibly stimulated by the work of his older and more illustrious contemporary, Pasteur, would try out the parasite theory in explaining malaria pigment

From the staff of Val-de-Grâce Military School of Medicine in France, Laveran was transferred to a military hospital at Constantine, Algeria. It was here, while examining the blood of a soldier suffering from paludism (or marsh fever as the French call it), that he discovered the parasite.

Quoting from his own work, "Du Paludisme et son hématozoaire," published in 1891 (Martin's trans., 1893), we read:

> . . . as I was trying to account for the mode of formation of the pigment in the palustral blood, I was led to see that besides melaniferous leucocytes, spherical hyaline corpuscles without nucleus could be seen, and also very characteristic crescent-shaped bodies.
>
> I had proceeded thus far with my researches and was still hesitating whether these e



PROFESSOR ALPHONSE LAVERAN
(1845–1922)

were parasites, when on November 6, 1880, on examining the pigmented spherical bodies mentioned above, I observed on the edge of several of these elements, moveable filaments or flagella whose extremely rapid and varied movements left no doubt as to their nature.

Laveran's discovery that malaria is caused by a parasite was not only the second high-water mark but, without doubt, the most important single event in the solution of the malaria problem. In recognition of its magnitude Laveran was appropriately honored by the French Academy of Sciences in 1889 and by the award of the Nobel prize for medicine in 1907.

The next baffling question was, how does the malaria parasite get into human blood?

On the Trail of the Mosquito

The scientific study of parasites had, in the meantime, been making rapid strides. One of the striking biological processes which this branch of knowledge had already made plain is the fact

that certain parasites spend part of their lives in one animal and the rest in another.

The first scientist to discover that man and the mosquito are joint hosts to a parasite was Sir Patrick Manson in 1878, when at Amoy, China, he discovered the part played by the mosquito in a disease called filariasis, a morbid condition resulting from the infection of the human body with certain worms (It should be stated, parenthetically, that the brilliant work of Dr Walter Reed on yellow fever and mosquitoes was not accomplished till 1899, in Cuba.)

Manson, who had become one of the leading figures in tropical medicine, later devoted himself to the malaria problem. Taking the conclusions of Laveran—elaborated by MacCallum in 1897—and reasoning from his own experience with mosquitoes, he advanced the hypothesis that the flagellum (which appears only when malarial blood gets outside the human body) is a means of facilitating the parasite's escape for the purpose of establishing a new life-cycle to be lived partly in water and partly in man.

Manson told these things enthusiastically to Major Ronald Ross, a young colleague who, in 1894, had returned to London from medical service in India, where he had been deeply impressed by the baneful influence of malaria and other tropical diseases. Having previously decided to study public health, Ross returned to India resolved to "follow the flagellum," as Manson advised, and to work out the entire problem thoroughly.

After much fruitless work, however, Ross discovered that the flagellum completely disappears soon after it enters the mosquito's stomach. He therefore abandoned Manson's hypothesis to the effect that the parasite escapes from the mosquito into water and that it later reaches the body of man by ingestion. He concluded that the parasite, in one form or another, must remain in the tissues of the mosquito until it reenters its human host.

For two years Ross worked untiringly, often under the most trying conditions. By trial and error he evolved his own technique for dissection and discovered that of the many species of mosquito only a few carry malaria It was at Secunderabad, India, in 1897, that Ross finally found malaria parasites in the stomachs of Anopheles mosquitoes which had been bred from larva and fed upon a human case of malaria

The dramatic details of this discovery are quoted from Ross's own "Memoirs."

> The dissection was excellent, and I went carefully through the tissues, not so familiar to me, searching every micron with the same passion and care as one would search some vast ruined palace for a little hidden treasure. Nothing No, those new mosquitoes also were going to be a failure: there was something wrong with the theory. . . I was tired, and what was the use? I must have examined the stomachs of a thousand mosquitoes by this time. But the angel of Fate fortunately laid his hand on my head; and I saw a clear and almost perfectly circular outline before me of about 12 microns in diameter. The outline was much too sharp, the cell too small to be an ordinary stomach-cell of a mosquito. I looked a little further. Here was another, and another exactly similar cell. The afternoon was hot and overcast; and I remember opening the diaphragm of the sub-stage condenser of the microscope to admit more light and then changing the focus In each of these cells there was a cluster of small granules, black as jet. . . . (the malarial pigment).

All that now remained was the experimental proof of this discovery. Owing to his transfer to Calcutta where human malaria was scarce, Ross used malaria-infected birds in order to trace, step by step, the complete life-cycle of the parasite. When this task was successfully completed in 1898, he triumphantly telegraphed to Manson, who reported the news at a meeting of the British Medical Association a few weeks later.

SIR PATRICK MANSON
(1844–1922)

Ross the Man

While Ross was working alone in India a group of Italian scientists were independently confirming his results at Rome. Later on, a long and bitter controversy arose between Ross and Professor Grassi regarding credit for the discovery. In the minds of such men as Laveran, Koch and Lister, however, there seems to have been no doubt about the priority of Ross's work. Moreover, the honors which sooner or later were showered upon him leave no room for doubt as to the world's appreciation of his work. He was elected to The Royal Society in 1901; awarded the Nobel prize for medicine in 1902; knighted in 1911.

Up to the time of his death in September, 1932, at the Ross Institute for Tropical Diseases, in London, he remained bitterly critical of the medical profession, largely for their apathy in adopting his proposals for the world-wide eradication of malaria.

Although trained as a physician he

preferred the title of scientist. His mind was extremely versatile as well as keen. His many volumes of poetry and prose are said by competent critics to be of extraordinary caliber. Certain of his published studies in mathematics are also said to contain unmistakable signs of genius.

THE INTERNATIONAL SCOPE OF THE PROBLEM

The final identification of the parasite-carrier soon resulted in the inauguration of vast anti-mosquito campaigns in various parts of the world. Comprehensive systems of drainage and screening have been adopted with great success in Italy, in Africa, The Federated Malay States, in Central America and more recently in the Southern States. At Panama, for instance, during the construction of the Canal, the technique of mosquito-eradication reached a new level of perfection. General Gorgas wrote to Ross in 1914:

> If we had known no more about the sanitation of Malaria than the French did, I do not think that we could have done any better than they did. Your discovery that the mosquito transferred the malaria parasite from man to man has enabled us at Panama to hold in check this disease, and to eradicate it entirely from most points on the Isthmus where our forces were engaged.
>
> It seems to me not extreme, therefore, to say that it was your discovery of this fact that has enabled us to build the Canal at the Isthmus of Panama.

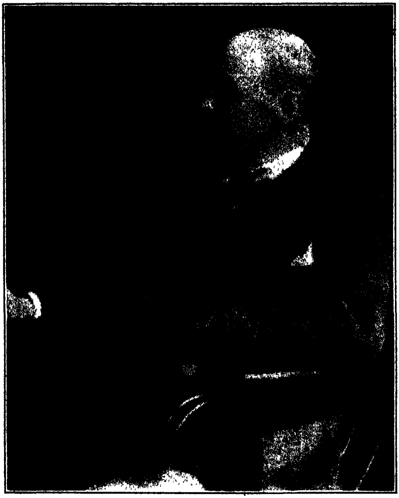
A great impetus was given to the world-wide campaign against malaria by the creation, in 1923, of the Malaria Commission of the League of Nations, a body whose primary object is to pool the experience of all nations with anti-malarial measures. In 1927, after careful study, this Commission concluded, among other things, that there is as yet no single method of eradication which can be described as superior to all others. "Malaria control is a local problem. . . . No country should follow slavishly the method used by another merely because it was successful there." The Commission also emphasized the need for a "continuous scientific study of malaria," specifically the problems of housing, medication, immunity, the biology of the Anopheles and the study of deltas.

That the practical problem of malaria is by no means solved, a careful study of the International Health Year Book, published by the League of Nations in 1930, will show. Malaria is still the great disabling and death-dealing disease of the tropics. In Ceylon, for instance, it is by far the most prevalent of all diseases. In the Philippines, in Turkey, in India, in the Malay States and in parts of Russia it ranks among the most important causes of disease and death. Even in Greece, Holland, Italy and Roumania it is still a menace to health and welfare.

No American, incidentally, can read the health reports of the League of Nations without a feeling of pride at the magnificent scope of the international health work of the Rockefeller Foundation. In 1929, for instance, in addition to its yellow-fever and hook-worm activities, it assisted eighteen foreign governments engaged in malaria campaigns, demonstrations or surveys, either by contributions to their budgets or by the loan of staff members who served as consultants.

MALARIA IN THE UNITED STATES

While malaria is no longer a serious problem in the northern states, it is, nevertheless, by reason of climate and economics, a disease of considerable importance in the South. Mortality statistics for the United States show that in 1929 there were 4,084 deaths from malaria in the registration area, or 3.5 per 100,000 of the population. Three fourths of these deaths occurred in the six Southern States listed below. It is significant, also, that the death-rate from



SIR RONALD ROSS
SHORTLY BEFORE HIS DEATH IN 1932.

malaria is generally higher in rural communities and amongst colored people.

DEATHS FROM MALARIA PER 100,000 POPULATION, SIX SOUTHERN STATES, 1929

Arkansas:	36.3	
White		29.3
Colored		56.4
Florida:	33.5	
White		26.0
Colored		51.3
Georgia:	23.5	
White		18.1
Colored		32.6
South Carolina:	22.0	
White		10.7
Colored		35.1
Mississippi:	20.4	
White		15.6
Colored		25.1
Alabama:	16.8	
White		12.3
Colored		24.8

That the presence of malaria in any community is evidence of a social and economic difficulty rather than a medical one, is a statement no one can now deny.

The effective demonstrations of the United States Public Health Service in a number of southern states proved this to be true twenty years ago. Moreover, the experiments initiated by the International Health Board in 1922 further proved that the small town or rural district can virtually rid itself of malaria at a per capita cost of from forty-five cents to one dollar per year.

Some Reflections

The conquest of malaria is a fascinating record of unmistakable progress. It is another example of man's collective victory over an insidious enemy in his natural environment; and it is heartening to consider it at a time when we are bewildered by our chronic failure to cope successfully with the social forces which also make up our environment.

It was, moreover, a triumph of means as well as of ends, for it could never have been done without the aid of the microscope and many of the other techniques known to science. Nor was it the work of a few great men. It represents, rather, the cumulative work of hundreds of obscure scientists whose specific contributions can never be identified, still less rewarded.

The story of this conquest—barely sketched here—also throws a flood of light on the incredible processes of biological evolution, especially the way in which one form of life interacts with another in the inexorable struggle for existence. It shows, too, how many of our current ideas of life in general and disease in particular are the vestiges of a pre-scientific era in which man's understanding of life phenomena was circumscribed by what he could see with his naked eye.

THE ORGANIZATION OF INCA SOCIETY

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THE communalism of primitive tribes has long been clearly distinguished by social scientists from socialism in advanced societies. Instances of the former are legion. Soviet Russia, the classic example of the latter, is not, however, the first but the second experiment of a great civilization with socialism. The first came to an end four centuries ago with Pizarro's conquest of Peru. In the last few years the researches of Baudin in France and Trimborn in Germany have revolutionized our knowledge of Inca society, and a review of the facts now known may prove illuminating and suggestive.

Only an acquaintance with the geographic environment can give an adequate conception of the magnitude of the achievement by which the Inca dynasty welded into a political and cultural unit ten million Indians of diverse tribes in a territory extending 2,500 miles from central Chile northward to the border of Colombia.

The Andes parallel the Pacific coast in two majestic ranges, the Eastern and the Maritime Cordilleras, forming a gigantic avenue lined with snow-capped volcanoes. The prevailing trade winds from the South Atlantic lose most of their moisture in the Amazonian jungle and on the forested eastern slope of the Eastern Cordillera. Enough reaches the inter-Andean plateau to produce a very moderate rainfall, but the winds are completely parched when they descend the Maritime Cordillera to the coast. The Pacific contributes fog but no rain. Consequently the narrow coastal zone is, except in the far north, a desert of windblown sand with no vegetation save a few cacti and fugitive plants. The monotony of this barren coastal strip is broken, at intervals of about thirty miles on the average, by bands of green—ribbons of vegetation which mark the courses of short, and often intermittent rivers fed by the melting snows of the Maritime Cordillera Only in the fertile but isolated valleys of the permanent streams is man able to live and thrive.

Between the two ranges of the Andes lies a plateau 12,000 feet in average elevation and from 100 to 200 miles in breadth. It is broken up, however, into large *hoyas* or drainage basins by numerous transverse ridges and ramifying spurs. A series of rivers, shallow, clear and swift, drain the several basins, pass to the east through mighty gateways or *pongos* in the Eastern Cordillera and plunge to the swampy lowlands to join the sluggish Amazon. The countless snow-clad peaks ranging from 18,000 to 23,000 feet in altitude, the wild labyrinthine gorges, the valleys sometimes a mile in depth and inaccessible from above, the land riven by earthquakes and seared by lava flows, all conspire to produce scenery of breathless grandeur. Although rich in mineral resources, the country supports only a meager mammalian fauna. The temperature varies little in any season from the annual mean of 50° F., but its range at different altitudes and at different hours of the day may be immense. The plateau is treeless except for occasional clumps of gnarled evergreens and for thickets of reeds along the streams. Grass-covered slopes alternate with rocky wastes, swampy moors and stretches of desert. The scanty vegetation never succeeds in moderating the

monotonous gray of the landscape. "It is never winter here, never spring, never summer; it is a land of eternal autumn."

Lacking in navigable rivers, poor in fauna and flora, surrounded by desert and jungle, its few habitable regions isolated from one another by barren wastes and almost insurmountable mountain barriers—an environment theoretically more unfavorable for the growth of civilization could scarcely be imagined. Yet civilization did develop here, stimulated by migrations and by cultural diffusion from Central America. By the beginning of our era, regional specialization had produced distinctive elaborations of the common cultural heritage in three widely separated parts of the area: the Chimu civilization on the northern coast of Peru, the Nazca culture in southern Peru, and the Tiahuanaco civilization in the Bolivian highlands. Between 500 and 600 A. D. the Tiahuanaco culture was spread, apparently by conquest, throughout the plateau and the coast. After three centuries of dominance, however, it suddenly collapsed through some unknown cataclysm and was succeeded by a period of disorder.

The Incas, though their origin is shrouded in myth, seem to have been one of the many small warring tribes which maintained a precarious economic and political existence in the highlands. Their chieftain and first historical ruler, Sinchi Rocca, about the year 1100, established hegemony over a group of tribes inhabiting one of the mountain valleys tributary to the Urubamba River. His successors, by a brilliant succession of conquests, established the Inca empire, which reached its maximum extent under the tenth ruler, Huayna Capac (c 1485–1525).

Life in Peru from time immemorial had centered in the *ayllu*, an exogamous clan united by common descent, usually in the female line, by the cult of a common totemic ancestor, and by the duty of avenging injuries to its members. Each clan laid claim to a definite territory and inhabited a single village of perhaps a hundred irregularly clustered huts of stone, mud or adobe.

The house, its furniture and an adjacent garden plot belonged to the individual family. The clan owned collectively, however, all land outside the village. Its members enjoyed equal rights to game, wood and pasturage on the communal forest and meadow, and they tilled in common a portion of the agricultural land for the support of the chief, the cult and the aged. The major portion of the cultivated land, however, was not communally tilled but was periodically distributed among the individual families to exploit for their own profit and at their own risk

Maize or Indian corn and the misnamed "Irish" potato constituted in most regions the mainstay of existence, supplemented by lima and kidney beans, squash, sweet potatoes, tomatoes, chili peppers, and other vegetables. The flesh of the domesticated dog and guinea-pig, fish, game birds, and an occasional deer served to relieve but slightly the predominantly vegetarian fare of the Peruvians

The llama and alpaca, the only large animals ever domesticated by an American Indian tribe, formed the basis of economic life in the regions too high or too arid for productive agriculture. They were too valuable as beasts of burden and for the wool they provided to be used very often for food. They grazed on the grassy uplands in large herds, each the communal property of a clan, and were driven once a year to the village to be shorn. The wool, which was equally distributed among the several households, together with cotton imported from the coast, was spun into thread by the women and woven on looms into the fabrics from which the

poncho-like garments of both sexes were made.

Food, shelter and clothing, in spite of certain regional differences, varied little within any particular clan. The chief alone towered above the common level of the clansmen, from whom he was distinguished by a higher standard of living, exemption from labor in the fields and the possession of private estates and herds. He held his position by various rules of succession, and his power ran the gamut from purely personal influence to military despotism. Clans, though sometimes politically autonomous, often united into larger groups or tribes on the basis of common descent, the need of mutual protection or the necessity of joint action in the regulation of irrigation In such cases the leader of one clan became the tribal chief while the others constituted a tribal council. In a like manner tribes were sometimes further compounded into confederacies and even into feudal states.

The Inca empire followed this typical evolution from clan to state. It went, however, a long step farther. The eighth ruler, Pachacutec (c. 1400–1448), transformed the irregularly organized feudal state, which he inherited, into a symmetrical hierarchy of groups and officials pyramided strictly according to a decimal system, and he initiated therewith a regulated system of production, distribution and consumption which bore most of the earmarks of what we have come to know as state socialism. And he accomplished this feat of statecraft with a minimum of violence to existing institutions.

The clan, the most vital institution in Peruvian life, was not destroyed. On the contrary, it was absorbed, virtually intact, into the imperial system, and became, indeed, the very cornerstone of that system. It was merely standardized. The Incas classified all males into ten age-grades on the basis, principally, of their capacity to work. The system took into account only the eighth of these, the so-called *purics,* men in the prime of life, between twenty-five and fifty years of age. Each *puric* was a married man, a householder and a laborer for the state as well as for himself The clan, as standardized, comprised exactly one hundred *purics* and hence received the name of "century." The former clan chief, instead of being deposed, was allowed to remain in office, he was absorbed into the official hierarchy as a "centurion." The century likewise retained the old clan lands. Its new artificial character even invested the latter with a new significance; common territory tended to supplant community of blood as the primary bond of association

The century was subdivided into ten "decuries" of ten *purics* each, of whom one was appointed "decurion" or foreman over the rest. Similarly ten centuries were grouped into a "phratry," and ten phratries into a "tribe," which therefore numbered 10,000 *purics.* The tribe and phratry corresponded to the earlier political confederations, and the former chiefs and petty kings usually remained in office although sometimes subject to the advice and control of resident Inca delegates. Four tribes formed a "province," over each of which presided a "governor" with highly important civil, judicial and military functions. The provinces of the empire were in turn grouped into four "quarters," each ruled by a "viceroy." These powerful officials resided at court and formed a sort of imperial council which advised the monarch and probably exercised a certain measure of limitation on his power.

In this administrative pyramid a steady stream of reports flowed up-

ward "through official channels," and a stream of orders flowed downward; there was no contact between functionaries of equal rank. A corps of secret agents, quite outside the hierarchy, circulated incognito through every corner of the empire to observe conditions, hear complaints and spy upon officials

At the apex of the pyramid stood the divine ruler, the Sapa Inca himself, directing the operations of the vast administrative machine with an authority not far from absolute. His subjects revered him as a god on earth, the son of the Sun, and approached his person only with uncovered feet and a symbolic burden on the shoulders He wore clothing of the finest wool, dined only from vessels of gold and silver and never used the same garment or utensil a second time. Although provided with numerous concubines, he had but one legitimate wife, the Coya, who, at least in later times, was necessarily his own eldest sister. The first son of this union, if sufficiently capable, succeeded to the throne. One result of such a brother-sister marriage was that the monarch's son was at the same time his nephew. This arrangement possessed manifest advantages in an empire where the patrilineal rule of succession prevailed in some regions and the matrilineal or uncle-nephew principle in others. The long line of Inca emperors reveals only one man of mediocre talents, all the rest displayed exceptional energy, resourcefulness, tolerance and magnanimity in the conduct of affairs. No dynasty with a higher average order of capacity has graced a throne in the whole of human history.

The Inca tribe, whose conquests established and then extended the empire, became transformed with the passage of time into a dominant aristocratic class, the Incas proper or *orejones*—"big ears"—as the Spaniards called them from their characteristic practise of piercing the ears for an ornamental plug and enlarging the hole until the lobes hung nearly to the shoulders. The members of this class, bound to the sovereign by ties of blood and common interest, filled all the more responsible civil, military and ecclesiastical positions. When not on active duty in the provinces, however, they resided at Cuzco, the capital.

A step beneath the Incas on the social scale stood the Curacas or provincial nobility, from whose ranks came most of the lesser officials, the heads of centuries, phratries and tribes In accordance with the cardinal Incaic principle of altering local institutions as little as possible, the chieftains of vanquished peoples were fitted into posts in the administrative hierarchy commensurate with their former positions, being removed only if they displayed irreconcilable hostility. The sovereign sought to win them over to active support of the imperial system by exemptions from local restraints, by generous gifts of property, servants and wives, and by grants of Incaic privileges in reward for faithful service. He further secured their fidelity by requiring their sons to reside at Cuzco—not only to serve as hostages but also to receive an Inca's education and thereby become imbued with the culture and attitude of the ruling class. By measures such as these the Curacas were gradually assimilated to the Incas, and the line of cleavage between conquerors and conquered was largely erased.

Between nobles and commoners, on the other hand, the line of demarcation grew correspondingly sharper and more rigid. The great mass of common people by their economic activities—mainly agricultural and pastoral—not only maintained themselves but also produced a surplus sufficient to support the classes which rendered only intangible services to the state: the officials,

nobles and priests. Such a surplus was assured, in part, by a body of sumptuary laws regulating and rigidly restricting the standard of living of the masses. They could not eat the choicer food delicacies or drink the more intoxicating beverages. They were forbidden to wear garments of fine wool or ornaments of gold, silver or precious stones. And they had no share in such prerogatives of the Incas and Curacas as the right to hold landed estates, receive an education, and practise polygamy.

The industrial life of the clan and village remained comparatively unchanged under the Inca régime. The conquering tribe divided all the cultivated land of the empire into three parts. The first and much the smallest portion belonged to the cult and was concentrated in the vicinity of the temples which its produce supported. The second portion, the property of the crown or state, consisted mainly of waste regions reclaimed for agriculture by the irrigation and other engineering projects of the conquerors. A small fraction of the state domain fell, through gifts from the sovereign for outstanding services, into the hands of individual nobles, sometimes as estates held for life only and sometimes as hereditary but inalienable and indivisible private property. The third and largest portion of the tilled land belonged to the centuries, which the conquering Incas were careful not to dispossess of their old clan holdings. Each century likewise owned communally its stretch of pasture and woodland, although the more extensive forests and grazing grounds were state property.

The arable land of the century was divided into strips of equal size, called *tupus*, each just large enough to support a married but childless couple. Some were tilled in common for the maintenance of the aged and incapacitated; the rest were allotted annually, under the direction of the centurion, to the heads of families, each of whom received one *tupu* for himself and wife, an additional strip for each male child, and half a strip for each daughter. On marrying, a son took over one *tupu* from his father, but a daughter's share reverted to the common fund. Each family cultivated its own plot and enjoyed undisputed possession of everything it raised. Hence the economic organization of the century was not, strictly speaking, socialistic or communistic, as some authorities have maintained. On the contrary, it followed the familiar pattern of agrarian collectivism, typified, for instance, by the Russian mir.

The agrarian community, however, became the basis of a truly socialistic superstructure. Instead of allowing free rein to personal interest and competition to achieve an automatic equilibrium of economic forces, the Incas substituted a rationally planned economy in which demand and supply were artificially regulated. The sumptuary laws stabilized and limited the demand, while the supply was cared for by a nationalized system of production superimposed upon the clan economy.

The first task was the support of the economically unproductive classes—the administrative hierarchy, the nobility and the priesthood. This was not accomplished, as we might expect, through taxation. Only in a few very exceptional cases did the state impose levies in goods upon its subjects. On the contrary, it followed the principle of the *corvée,* namely, that tribute should take the form of personal services. Every able-bodied householder or *puric,* besides cultivating his own plot of ground to support his family and cooperating with his clansmen in tilling the undistributed lands of the century to provide for its less fortunate members, was expected to devote a portion of his time and labor to

the service of the state. This contribution took the form, primarily, of labor on the lands of the crown and the cult. The men, while at work, were fed, entertained, and provided with seed and other necessities at public expense The products contributed to the support of the official and ecclesiastical hierarchies.

The pastoral economy paralleled the agricultural. In the highlands each *puric* possessed a pair or two of llamas and had the right to use their wool and to kill their offspring for food Small herds were owned communally by the centuries and privately by the Curacas The crown and the cult, however, possessed enormous herds of llamas and alpacas. The *purics*, as part of their labor obligation to the state, took turns in tending these animals and performed assigned tasks at the periodic shearings and slaughters The wool, hides and meat, of course, flowed into the warehouses of the state.

Although clansmen were privileged to secure small game on the woodland belonging to the century, the hunting of the larger wild animals was a state monopoly. Once a year the governor assembled the *purics* of his province for a great communal drive on one of the national forests. Surrounding a wide territory, the men advanced with a deafening din, penning their quarry in an ever narrowing circle. All beasts of prey—pumas, bears, foxes, wildcats—they slew on sight with arrows, darts and clubs In the case of deer, they killed only a portion of the males, sparing all the does and best bucks lest the supply become depleted. The guanaco and vicuña, wild cousins of the llama, were captured alive with the bola—a rope weighted at the ends with stones. When thrown, this weapon wrapped itself around the legs of the animal, bringing it to the ground. The victims were shorn and then released except for a certain proportion of the males selected for slaughter. The hunters feasted on part of the meat. The remainder, together with the hides and fleeces, belonged to the state

Mining, too, was nationalized. The Peruvians obtained gold by panning river gravels and extracted silver and copper ores in pits or short galleries. Miners were drafted for a term of one month a year and in this way performed their labor obligation to the state, which, of course, owned the product.

An important part of the tribute obligation of the *puric* consisted in labor in the construction of public works. As soon as a new province was conquered, for example, a complete census of its population, land and resources was taken; the monarch with his council laid plans for the construction of needed roads, fortresses, irrigation systems, etc.; and an army of engineers and drafted laborers was put to work Mountain slopes were reclaimed for agriculture by terracing them with rows of stone retaining walls like gigantic steps. Swamps were drained and water was brought to arid lands by constructing systems of canals, reservoirs, aqueducts and sluices. The reclaimed lands became the property of the state, which could thus afford to leave the clan holdings intact.

Similar levies erected the Cyclopean fortresses, temples and palaces at Cuzco and elsewhere. The architectural skill of the Peruvians is attested by the fact that blocks of stone thousands of cubic feet in dimension were fitted to each other, without mortar, so accurately that a knife blade could not be inserted between them.

Drafted labor likewise built and maintained the roads. Two main highways traversed the empire from north to south, one along the coast, the other in the highlands. Numerous transverse and secondary roads formed a giant network converging on Cuzco. The

highways ascended mountains by steps hewn out of solid rock. They spanned streams on stone culverts, rivers on pontoon bridges, marshes on causeways, and gorges on marvelous suspension bridges moored to masonry piers

At intervals of every two or three miles stood post houses, where two or more couriers were always in attendance When a runner from the next station approached, a fresh courier would run alongside to learn the message or receive the burden and then dash off for the next post without slackening of pace Every twelve to eighteen miles along the roads stood an inn with accommodations for travelers and a cluster of twenty to fifty small rectangular storehouses stocked with food, clothing and arms.

The rigid decimal organization of society, which appears so arbitrary at first glance, becomes comprehensible when we regard it as an adjustment to the system of tribute by labor in lieu of taxes. Lacking a written language, the Peruvians were able to keep records and deal with large figures only with the aid of the *quipu*—a thick cord from which hung a fringe of colored and knotted strings, the colors representing classes of objects, the number and position of the knots denoting numerals Since the *quipu* lends itself to computation only in terms of decimals, the Incas could devise only one equitable way of levying drafts of labor, namely, by fixing a quota for a large group, assigning one tenth of the quota to each constituent sub-group, and so on. Thus, if 1,000 men were needed from a particular tribe for a construction project, each phratry would have to furnish 100, each century ten, and each decury one. If the units had varied in size, *e g.*, if some centuries had had fifty *purics* while others had two hundred, the smaller units would have contributed disproportionately and the tribute burden would have been inequitably distributed. It was imperative, therefore, to maintain the various units at approximately their standard size.

Once a year each decurion reported to his superior the number of births and deaths in his ten families. These figures were transmitted through official channels to the provincial governor, who had them compiled by an accountant, reported the total to the emperor, and turned over the records to the official *quipu* keepers at Cuzco On the basis of these statistics the state imposed a permanent levy upon each group which appreciably exceeded its ideal population The surplus thus drawn off was, in part, formed into *mitimaes* or colonies, which were granted special privileges and exemptions, and were transported to man military outposts, to settle underpopulated areas, to introduce Incaic culture to backward regions, or to replace rebellious tribes removed to safer sections. From the surplus not absorbed in *mitimaes* were recruited two anomalous classes in Inca society: the *yanacuna* and the *acllacuna*

The *yanacuna* consisted of men levied as youths for the personal service of the monarch. He employed them as palace attendants, devoted them to the temples for similar services, used them as porters in the army, presented them to officials as domestic servants or as serfs to till private estates, assigned them minor administrative posts such as the supervision of warehouses, or had them trained in specialized handicrafts. They lost their clan rights and also all duties except to their masters, but their status, though hereditary, was scarcely that of slaves. They fared, on the whole, rather better than the *purics*. Being in a position to gain the confidence and favor of their masters, they were frequently rewarded with rich gifts and even with landed estates and official positions, to which the commoner could never aspire.

The *acllacuna* or so-called "Virgins of the Sun" formed the second anomalous class. Selected at the age of eight or nine from overpopulous centuries, they lived in convents under the supervision of matrons Some, at the age of fourteen, took vows of chastity and became priestesses. The majority, however, at the will of the emperor, became imperial concubines, married *yanacuna,* or were bestowed upon favored nobles as secondary wives. The *acllacuna,* too, lost their clan membership, yet acquired an enhanced social status.

These special classes, though never very large, nevertheless filled an important place in the Inca economy. Besides rendering personal service in palace and temple, they carried on the specialized arts and crafts. Except for them, a division of labor in production, other than by sex, scarcely existed in Peru. Each clan, indeed each family, was practically self-sufficient economically. Every commoner was a Jack-of-all-trades, conversant with all save a few luxury arts such as metal working and fine weaving, and it was these that were carried on by the classes in question.

Yanacuna smiths worked with gold, silver and copper. They understood how to make bronze by mixing copper and tin in the ore, and how to plate one metal with another by hammering and by the use of mercury amalgams. Perhaps nothing better reveals their skill and artistry than their ability to fashion golden butterflies with wings one tenth of a millimeter in thickness, so light and so well balanced that when thrown they soared like toy airplanes before falling The precious metals and their products poured into Cuzco, which was a veritable El Dorado. The temple of the Sun, for example, had a golden garden where trees and plants, fruits and flowers, birds and insects were all of gold, and where grazed a herd of golden llamas under a life-sized golden shepherd.

The *acllacuna,* working in the convents under the direction of expert matrons, wove the fine fabrics of vicuña wool and supplied the ruler, the higher officials, and the priests with their rich garments In skill and technique in the textile arts the ancient Peruvians have had no equals, even among European peoples. Their tapestries, for example, in harmony of colors, fastness of dyes and perfection of technique, are stated by experts to surpass the finest Beauvais and Gobelin products.

The collectivistic economy of the clan or century provided automatically for most of the needs of the masses The superimposed régime of the state restricted popular consumption by sumptuary laws It assured a surplus production of manufactured goods through the special classes of *yanacuna* and *acllacuna,* and of raw materials through the general requirement of labor on the lands, in the mines, and with the herds belonging to the state. What marks it indelibly as socialistic, however, is its system of distribution. It achieved an equilibrium of production and consumption, not through the free interchange of goods, but through state-supervised periodic distributions of the surplus production.

In this system the warehouses strategically located in clusters along the highways played a vital part. Into them flowed a steady stream of raw and finished products from the crown and cult lands, the state herds, the mines, the organized game drives and the specialized handicrafts. From them the state drew: (1) means of subsistence and luxuries for the ruling, official and priestly classes, their servants and the artisans, (2) food and military stores for armies on the march, (3) raw materials for manufacture into finished goods, (4) support for *purics* engaged in public work, (5) supplies to relieve regions stricken with famine or crop failure, and (6) consumption goods for

the masses in all cases where the latter could not supply themselves. Since the warehouses contained reserves of food sufficient to support the entire population for several years, and corresponding quantities of other articles, the system provided adequate insurance against privation. The supervisors made periodic reports, which were tabulated and preserved in the archives at Cuzco Thus the authorities always knew the exact status and location of the reserves, and could order their transfer by porter or llama train from well-stocked regions to those with a shortage The people received distributions of staples, such as meat, wool, cotton, seeds and tools, periodically, and of other articles whenever the statistics revealed a surplus above necessary reserves. Distributions, like levies, took place by successive allotments to tribe, phratry, century, etc , each family thus received the same as its neighbor, irrespective of its individual needs. Under this system economic life pursued an even course undisturbed by the boom periods and depressions which result from leaving the adjustment of production and consumption to automatic forces.

Travel and transportation were public functions. No one used the roads except couriers, officials, soldiers, colonists, authorized pilgrims and porters To be sure, the state carried on a heavy traffic in the interchange of regional products, but private trade was confined within very narrow limits. At local markets, held thrice a month, families exchanged—by barter, for there was no money—the surplus products of their fields and unneeded articles received from the state. These markets served principally to adjust the inequalities resulting from the rule-of-thumb system of distribution. The limited range of private property, the sumptuary laws and the state's participation in the circulation of goods effectually prevented the development of trade on a broader basis. Even foreign trade, as in Soviet Russia, was a government monopoly.

Inca socialism, absurdly idealized by some writers and as unjustly dismissed as a fiction by others, emerges from a survey of the facts, not as the product of a Utopian dream, but as a natural adaptation to a special set of conditions. To the conquerors it assured power, position and luxury, to the conquered, economic security, the essential preservation of local institutions, and probably an enhanced standard of living. Pragmatic rather than dogmatic, it sought, for example, not to extirpate commerce and private property on principle but rather to limit them on practical grounds Socialism, linked with democracy in Marxian theory, was consistent in Peru with monarchy and aristocracy. The Inca system exerted a leveling influence, creating a uniform standard of living throughout the empire. But if it thus realized the ideal of equality, it was equality only within a given social class. It subordinated the individual to the state, regimented and controlled his life from birth to death and left little scope for personal initiative and ambition. On the other hand, it achieved an exceptional measure of law and order, it prevented the waste of natural resources and it eliminated entirely the hazards of poverty and involuntary unemployment. In general, it displayed many but not all of the virtues for which socialism has been exalted and many but not all of the defects with which it has been charged. We should not forget, however, that it was a working system and not a theory.

WHERE IS PHYSICS GOING?

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EVERY one is interested in the newest trends of contemporary physics, and on all sides one notes a feeling of wonder at just what is going to happen next. It will doubtless be considered presumptuous on the part of any one to attempt an estimate of the probable direction of physical progress during the years immediately ahead. Indeed it would be possible to take the attitude that the attempt is meaningless, and to use as justification the dictum of the celebrated writer who said: "Going there is more important than getting there and to travel hopefully is better than to arrive." There is a sense in which the zest and fun of *doing* things scientific outweigh consideration of the aim and ultimate goal of these activities. Contemporary writers never tire of pointing out the essential disinterestedness of scientists in their search for knowledge for its own sake and the danger of any attempt to force scientific research into any specific channel. Nevertheless, a study of the history of science and physics in particular reveals the existence of certain methods of attack on physical problems which persisted through relatively long periods, finally to be supplanted by what seemed to be more promising schemes. Consequently, there can not fail to be interest nowadays in the question What is likely on the basis of present evidence to be the general fashion in physical theories in the immediate future? It is with this question that we wish to concern ourselves in this paper.

In the first place, what is the task of physics? Reduced to simplest terms it is the description of a certain portion of human experience. This description is carried through by the building of physical theories forming the basis of what may be called the physical world, a world constructed in the mind of the physicist, but which he tries to make correspond as closely as possible to the world of experience Physical theories are of many types, corresponding to the diversity of phenomena, but the natural aim dictated by both esthetic and economical reasons is to reduce their number to the smallest possible. The history of physics during the immediate past shows a tendency to emphasize two main types of theories which have received the names *mechanical* (or dynamical) and *statistical* A mechanical theory of a set of physical phenomena is based on the assumption that the thing which in the physical world corresponds to the phenomena in question is a mechanical system, *i e.*, essentially a system of particles moving in space and time in accordance with the principles of classical mechanics The details of such a theory require no consideration here. However, there are two very significant properties of the method of physical description involved in a mechanical theory. The first is that of *determinism,* the second *reversibility*. By determinism is meant simply the fact that if the state of a mechanical system is known at any instant its state is completely determined for all time, past or future. Thus the knowledge of the state of such a system at any one time enables one to predict what it will be at any other time. This property of determinism or predictability is of course in agreement with the doctrine of causality and has in the past been considered one of the strongest points in favor of mechanical

theories. During the last century this method was pursued with relatively great success, as may be seen from the mechanical theories of fluids, acoustics, electrical currents, optics, etc. The implication of reversibility is that there is no preferred direction of change involved in a mechanical system. The equations of classical mechanics do not distinguish between the positive and negative directions along the time axis By a suitable change in conditions a mechanical system may traverse its path backward. A ball rolling down an inclined plane will, if the opportunity is offered, roll up again and to the extent that it constitutes a dynamical system will roll up to a height equal to that from which it originally fell The actual experiment does not have quite this result, that is, the ball does not reverse itself exactly we have to admit that its behavior is not quite reversible. In fact, observation shows that the phenomena of nature are always more or less irreversible, and this might have constituted a very serious objection to the use of mechanical theories for their description were it not for the fact that in a great many cases the irreversibility can be neglected in comparison with more important aspects of the phenomena.

The second important type of physical theory, namely, the *statistical*, is characterized by its renunciation of the concept of determinism and its emphasis on the average behavior of physical systems The kinetic theory of gases, for example, is a statistical theory in that it makes no attempt to follow the destiny of each individual molecule of a gas, *i.e.*, to predict exactly what its position, velocity, energy will be at any given instant; rather it seeks merely to know how many molecules on the average will lie in a chosen volume, how many molecules on the average have their velocities included within certain limits, etc. By this method much valuable description of the behavior of gases has been made possible in good agreement with experimental facts It would be quite wrong to suppose that such a theory does not predict new phenomena; we must only emphasize that its prediction always refers to average behavior and that therefore its assertions have only a certain degree of probability Statistically speaking, the second law of thermodynamics, for example, describes the behavior of physical systems only with a more or less high degree of probability, never with certainty. Moreover, by virtue of its use of probability the statistical method involves the possibility of describing irreversible phenomena. Hence it stands in sharp contrast to the method of classical mechanics.

A question which is provoking considerable discussion among physicists at the present moment is. Which of these two types of theories is to prevail ultimately in the construction of the physical world? The reason for this eager interest is to be found of course in the rapid development of the newer theories of the structure of matter based on the quantum concept In the previous century the choice between mechanical and statistical theories was largely decided by the criterion of convenience. Whenever the problem was one of describing the behavior of a system with a large number of degrees of freedom (*i.e.*, containing a great many entities) the statistical method at once suggested itself as the natural approach. There was, however, no suggestion that the strict application of classical mechanical concepts to such a problem was wrong in *principle* This situation has been radically altered by the introduction of quantum mechanics. If the latter is expressed in terms of our usual space and time concepts, it involves the necessity as a matter of principle of treating statistically the behavior of even a single

electron Through the famous indeterminacy principle of Heisenberg it renounces the possibility of predicting the state of an electron or system of electrons at any instant and reduces our knowledge of such states to probabilities only This amounts to indeterminism in the microscopic realm of atomic physics and therefore *a fortiori* logically to indeterminism in all physical phenomena. At any rate to many physicists there seems no way of escaping this conclusion It has naturally excited much interest among all those to whom the progress of science is a matter of moment, for it appears to mark a decided trend away from the point of view of that classical mechanics to the use of which so much past progress has been due

The conclusion just mentioned, however, has by no means gone unchallenged and it will be worth while to examine the views of some of those who are inclined to look at the situation more conservatively. Foremost among these is Max Planck, himself the propounder of the quantum theory which has had so much to do with the development of the new tendencies. He emphasizes the view that in any discussion of the methods of physics one must be careful to distinguish between the world of experience (*viz*, the world of laboratory operations, etc) and the physical world which is created by the mind of the physicist to describe the former. No one can believe in exact determinism in the former, for, in spite of the approximate regularity of experience, not even the most delicate of physical experiments are *exactly* predictable in their results. Nowithstanding this, physicists have not hesitated to use the idea of causality or determinism in the physical world and in general, we must all realize, with considerable success. The indeterminacy comes merely with the transition from the physical world to that of experience In similar fashion one might argue that it should be possible to construct a quantum mechanical theory which is completely deterministic and which moreover leads to laws that are found to describe experience in the atomic realm with as great accuracy as that with which the laws of classical mechanics describe large-scale physical phenomena Now as a matter of fact this is admitted to be true as long as the primitive concepts of space and time appear nowhere in the theory or in its application It is clear that it is the use of these ideas which leads to the new indeterminism. Foregoing or renouncing these implies, for example, that it is really meaningless in physics to contemplate the simultaneous measurement of the position and velocity of an electron, and in general that the space and time concepts which we use in macroscopic physics are wholly inadequate to handle microscopic phenomena There is indeed a difficulty about this view which we shall examine a little later Into the more metaphysical aspects of Planck's views it is probably unwise to enter here at any length. But it is felt that physicists will be mildly interested in Planck's speculation about an ideal mind which is sufficiently objective with respect to our world that it is able to predict all phenomena, thus transcending mere man, who, being himself a part of nature, is never able to achieve complete objectivity in his study of it

The attitude of Schrodinger, the creator of the wave mechanics which has proved such a powerful weapon in the theoretical attack on atomic problems, is of course also of great significance. While probably less conservative than Planck he is plainly cautious in his emphasis on the truism that no one can prove that a deterministic theory of all physical phenomena is not ultimately possible. To be sure this is rather cold comfort to those who feel that they are

confronted by an existing condition which demands a clear-cut attitude rather than one of vacillation. However, Schrödinger strengthens his thesis by calling attention to the fact that even in classical mechanics there exists an element of indeterminism which has to be removed by appropriate devices We recall, for example, that if we know merely the *position* of a particle at a given instant the laws of mechanics do not suffice to predict its position at any other instant; in fact, the latter is undetermined In order to make it determinate it is, of course, necessary to specify the *velocity* as well as the position at the given instant It is only when this is done that the past and future states of the particle are predicted Instead of the velocity one may use the position at two separate instants. If the latter are close together we are of course led to the concept of velocity in differential notation. Determinism in mechanics thus results for the use of the appropriate number of initial or boundary conditions[1] as well as from the nature of the laws which are employed. The thought occurs that a similar situation may exist in quantum mechanics that if we were to introduce a sufficient number of parameters the indeterminism involved would disappear No one appears to have considered this possibility seriously, possibly because the fixation of boundary conditions (no matter what their number may be) implies measurement, and the indeterminacy principle of quantum mechanics denies the possibility of a simultaneous measurement of the quantities necessary for a specification of the conditions. This is equivalent to saying that any attempt to localize the electron, or any particle for that matter, involves a renunciation of knowledge of its subsequent path Let us examine a little more closely the corresponding situation in classical mechanics The very concept of a particle as having a position in a given reference system at every instant implies that it possesses in its motion a *continuous* path. Now no experimental observation is ever competent to determine such a path, for no such observation can ever hope to fix anything but a finite, discrete set of points. Strictly speaking, in so far as a physical law purports to be a description of laboratory operations and observations, the functions used should for this reason be discontinuous However, in the method of description employed by classical physics, we avoid what would be considered undue complexity by smoothing out the discontinuous functions into continuous ones, *i e*, we draw smooth curves through discrete points by a process of judicious interpolation. This is not the place for a thorough investigation of the justification of this scheme, which indeed might strike the casual non-scientific observer as being rather gratuitous, not to say risky We may merely remark that in general the physicist feels he is safe in making the interpolation in question if there exists an operation or set of operations by which he can at any rate in principle check *any particular* interpolated value. To make this point a little clearer, let us imagine the special case of the path of a projectile. We suppose that there exists an experimental scheme for plotting the position of the projectile at various instants of time. A smooth curve is drawn through the various positions and is called the path of the projectile For we feel that our method would allow us to ascertain the position at *any* other finite discrete set of time instants and hence to check the curve drawn on the basis of the first set. Of course, we must also make the assumption that it is very unlikely that the new

[1] See R. B. Lindsay, "The Significance of Boundary Conditions in Physics," SCIENTIFIC MONTHLY, Vol. 29, 469, 1929.

set of positions will fall very far away from the curve. If we were to encounter a situation in which there no longer existed such a means of checking the interpolation, we might be wiser not to attach much value to the smoothed-out curve and function. Now it is possible to take the stand that this is precisely the situation we encounter in atomic problems. We indeed have experimental devices which make possible the photography of so-called "tracks" of atomic particles, but it must not be forgotten that we have not that measure of control over such experiments which makes possible the verification of the interpolation involved in the pictures of such tracks. The situation is even more hopeless when we consider the "motion" of bound atomic particles like electrons in an atom. There would appear to exist no operation by which such "motion" can be experimentally observed. The conclusion which some would like to draw from all this is that there is then no meaning to be attached to such motion or to the paths of such electrons; hence atomic theory should not involve such considerations at all This attitude was to a considerable extent responsible for the introduction of the new quantum mechanics (Heisenberg) in 1925. Obviously, it would tend to make the application of the indeterminacy principle to atomic motions illusory and would leave the way open to a deterministic theory in which atomic paths and motions have no place. The possibility of this view-point has already been indicated above in our discussion of Planck's view.

At this very point, however, we encounter a grave difficulty which has been emphasized by Niels Bohr, the founder of the quantum theory of atomic structure, whose work is responsible for the whole of contemporary atomic mechanics and who has probably thought more deeply about the methodology of modern physics than any other man. Bohr's attitude is an interesting mixture of the conservative and the radical. It is conservative in the sense that it is founded on the conviction that physicists are unable to get away from thinking in terms of space and time since all experiments are carried out with these categories uppermost in mind. On the other hand, Bohr believes quite thoroughly that we are forced to renounce a unified, causal view of nature. This renunciation is involved in what Bohr calls the principle of "complementarity," which expresses the hypothesis that we must in our analysis of nature necessarily encounter mutually exclusive modes of description which may therefore be said to stand with respect to each other in a complementary relationship It must be stressed that there is involved here something deeper than mere alternative theories, either one of which may be applied indifferently according as we wish to stress now one and now another aspect of the situation. Such theories have of course long been recognized for example, so far as the phenomena of calorimetry are concerned it is a matter of indifference whether we use the theory which looks upon heat as a substance or that which considers it a form of energy; again, so far as the large-scale phenomena of electrostatics are concerned, we may employ indifferently the theory which looks upon electricity as a *continuous* fluid or the electron (atomistic) theory. The natural aim of physics is to remove theories from the indifferent class by imposing more stringent requirements on them. Thus, to consider again the heat illustration, it is well known that the energetical theory of heat is much more competent to describe the whole range of observed thermal phenomena than the substantial theory. Hence from the larger point of view it is no longer a matter of indifference which theory is held. We are present-

ing this digression for the purpose of emphasizing the wholly distinct and novel place occupied by the complementarity idea in contemporary physics. The significance of the latter may be made clear by one or two examples. It is now well known that in the description of optical phenomena all observations having to do with the propagation of light are best described in terms of the wave theory, while all observations connected with the emission and absorption of light are best handled by means of the quantum theory, which has introduced into optics the atomistic view-point. No one has ever succeeded in representing *all* the phenomena of light by means of *either* theory, and the point of view of Bohr is that there is an essential limitation in human methods of describing experience which prevents the building of a single unified theory of light. If we wish, for example, to describe the interference patterns which are formed when light from a given source passes through two openings in a screen and then falls on another screen, we must use the wave theory. If, for example, we were to attempt to account for the patterns from the light quantum or photon point of view we should have to say that more photons fell on one part of the screen than on another part. This would in turn involve tracing the paths of such photons. But the attempt to do this experimentally only leads to the complete obliteration of the interference pattern or the very thing which is to be described It is true that many attempts have been made to discuss light propagation in terms of photons. It must be admitted that so far they have not been successful. Bohr's thesis is that in the very nature of things they never can be successful, for the wave description and the particle description are mutually exclusive, complementary methods: the use of one automatically excludes the use of the other. It may indeed happen that some one *will* discover a way to reconcile the two points of view and make them essentially indifferent hypotheses. In that event Bohr's generalization would fall It must be admitted, however, that he has a strong case. The situation encountered in optics occurs in every case where the Planck constant of action "h" appears, and therefore leads to the feeling that wherever the quantum theory has to be used we are at a threshold, so to speak, marking the limitation of human descriptive ability. To take another illustration, the description of atomic phenomena appears to demand the quantum theory. Thus an atom is assumed to exist only in certain so-called "stationary" states of great stability, and every alteration of the atom must take place from one of these states to another Now suppose one were to try to describe such an atom in terms of space-time motions of particles (*i e*, the assumed elementary constituents of the atom) This would ultimately involve measurement of position and velocity of the atomic particles But the attempt at measurement would so disturb the atom that the stationary state concept would no longer have any meaning One might object that it should be possible to estimate pretty exactly the amount of disturbance which is produced by the measuring instruments. Strictly speaking, this is possible only if the instruments themselves can be included in the system (in this case, the atom) being investigated. But the whole purpose of a measuring instrument is to yield information about something objective to and separate from itself. Hence it can not be included in the observed system without losing the objectivity which is the essential feature of scientific description. We therefore reach the conclusion that the quantum theory concept of stationary atomic states is complementary

to a space-time description of atomic behavior. Each mutually excludes the other.

The idea of complementarity may be made somewhat clearer by a simple experimental analogy. Imagine a rectangular box divided into two equal compartments with a single die in each part. The box has a glass top, but there is further an opaque cover which can slide back and forth concealing entirely one compartment from view while the other is exposed. The sliding of the cover is so arranged that when it takes place an impulse is communicated to the dice which is equivalent to shaking them.[2] Now when the slide covers one compartment an observer can note the aspect of the die in the other compartment. This is, so to speak, equivalent to a measurement. In order to conduct the associated measurement of observing the aspect of the other die, the cover slide must be moved over so as to leave the corresponding compartment visible. But the process of doing this creates a disturbance so that when the aspect of the second die is noted, the observer no longer knows which face of the first die is uppermost. We may say that his knowledge of the aspect of the one is complementary to his knowledge of the aspect of the other. Any attempt to note both *exactly* is doomed to failure: he can at best estimate the probability of any pair of associated readings. If he wishes to know exactly the aspect of the one he must renounce exact knowledge of that of the other at the same time. It is important to realize that the reason for this complementarity is precisely the disturbance involved in the measurement and the impossibility of estimating the magnitude of this disturbance. To be sure, an observer who understood thoroughly the construction of the box and knew the exact relationship between the impulse communicated to the die and the motion of the slide might be thus enabled to predict the precise aspect of each die for every observation. But even then, since he can never see both dice simultaneously, he could never be exactly sure that his theoretical prediction was true and indeed could never verify it except by making another "measurement," which would again introduce the necessity for a further calculation, the verification of which would necessitate still another measurement, and so on indefinitely. Bohr insists that this is quite analogous to the actual situation existing in physical description. Every attempt to account theoretically for the disturbance introduced by a given measurement involves another measurement for its verification: one is therefore led to an infinite series of observations before exactness can be obtained. In large-scale physical observations the disturbances may be made so slight compared with the measured effects that they *may* be sufficiently accounted for and compensated within what we call the limits of experimental error. Hence in this realm we do not feel any drastic need of the complementarity idea. But the situation is different in the microscopic domain of atomic measurements, for here the disturbances introduced by the measurement are of the same order of magnitude as the quantities being observed. Here then the essential limitation of our descriptive ability makes itself most keenly felt. Bohr's conviction of this limitation as leading to an inevitable renunciation of a complete understanding of physical phenomena in terms of both space-time concepts and causal explanation has led him to the interesting extrapolation that for similar reasons we must renounce a complete understanding of life and accept it as an ele-

[2] A box of this nature was on exhibition in the Danish Room of the Hall of Science during the Chicago Century of Progress Exposition, 1933.

mentary fact. All our attempts to learn what life is involve disturbance to living processes which enable the living organism to conceal from us the information we seek.

Such then is the extremely interesting attitude of Bohr! In so far as physics is concerned it is supported by such a wealth of illustrations as to make its plausibility plain. At the same time there are doubtless some who will look upon it as the expression of a kind of "defeatism" psychology. Does it not perhaps confess human limitations too readily? If accepted whole-heartedly might it not color in too pessimistic fashion the immediate future of physics? We realize, of course, that the complementarity idea is based wholly on the quantum theory, *i.e.*, on the existence of the quantum of action, "h" If it were not for the atomicity of action the principle would imply no more than our usual admission of error common to all measurement. But it is precisely the assumption of the existence of a *smallest* quantity of action which forces us to admit the fundamental limitation implied in the principle. Now, of course, the quantum theory was invented to describe certain phenomena. There can be in the nature of things no proof that there exists no other possible theoretical description of these phenomena than that involving the quantum of action. Human ingenuity may yet invent a new point of view, and the reading of the history of physics does not encourage idolatrous worship of current physical theories, no matter how temporarily successful they may appear to be. Does it not then seem rather hasty to infer a fundamental limitation of human ability to describe natural phenomena from the success of a single physical theory? Some may prefer to believe that such a deduction from a physical theory casts extra suspicion on the latter rather than strengthening our belief in the former. The quantum theory has been so very successful, however, that the burden of proof probably falls on those who would oppose it, no matter how strongly they would like to see the embarrassing "h" taken out of nature!

Another important point in a critique of the complementarity idea is the rôle which space and time play in physics. About this much has been written, but it seems certain that there is still much left to argue about. It is difficult to believe that the primitive space and time notions in terms of which physical operations are carried out and physical description is made have reached their final form. We are forced to conclude that if man has evolved, his space-time orientation has also gone through an evolutionary process and there seems no reason to suppose that this process is now complete. Indeed our views of space and time have already in relatively recent time undergone considerable change as far as their scientific use is concerned in the development of the theory of relativity with its introduction of non-euclidian space and four dimensional space-time. One may remark that these matters may have little influence on people's primitive concepts. But that is not the important point. The significant thing is that for the sake of progress in physics it has already been considered desirable to modify and refine the primitive ideas. Hence there can be no artificial limit imposed on this process. As an illustration the present author would like seriously to propose the ultimate elimination of the use of the concept of time in physics. When it is considered that in physics time enters only as a variable parameter whose values may be put into one-to-one correspondence with the points on a line, *i.e.*, a non-denumerable continuum, and is introduced merely for the more convenient comparison of physical systems, and when it is further considered that

all time measurement reduces essentially to space measurement using arbitrary physical systems (*i.e.*, various kinds of clocks) the interesting question arises whether ultimately one might not avoid some of the embarrassments of contemporary physics by abandoning the parameter altogether in favor of direct comparison of physical systems. This is, to be sure, not the place for a complete airing of this view. It is merely a concrete suggestion as to how our use of space and time in physics may alter and in such a way as to remove the necessity for such a principle as that of complementarity, by removing the very concepts in terms of which the idea of complementarity is expressed. Such a step would probably make physics more "difficult." But that has been said to be the case with the introduction of almost every physical theory involving a conceptual change. The argument that a physical theory shall be *simple* has proved illusory. All we can ask is that it shall yield a set of laws (*i.e.*, relations among symbols) which, when the symbols are properly identified, shall agree with experimental observations, the latter being ultimately nothing but pointer-readings. The aim of theoretical physics is to develop new laws which subsume existing experimental observations more completely and moreover predict new ones, so that there shall exist no laboratory operation, the resultant pointer-readings for which are not predictable in advance.

The point of view of complementarity strikes so deeply at the concept of deterministic description that a thorough critique is hardly possible within the limits of an article like the present which confines itself to pointing out general trends. It is, however, rather tempting to consider briefly one more possible method of making progress in physics and overcoming present dilemmas. Up to this point in our discussion we have tacitly assumed, as is always done in theoretical reasoning in physics, the laws of Aristotelian logic, *viz.*: (1) The law of *identity*—everything is identical with itself, which really expresses the assumption that definite concepts are possible and that once a thing has been identified in clear-cut fashion it retains that identity; (2) the law of *contradiction*—a thing can not both be and not be, *i.e.*, the same object can not be both hard and not-hard at the same time and place, or soft and not-soft; (3) the law of *duality* or the *excluded middle*, as it is more commonly called—a thing must either be or not be, *i.e.*, an object must be either hard or not-hard, there is no third possibility. Of two assertions which really contradict each other, one must of necessity be true. In the third law it must be emphasized that the assertions must be contradictory and not merely opposite. Thus the law does not say that an object is necessarily hard or soft. All logical thinking as commonly understood can be shown to depend in the last analysis on these so-called laws of thought. In particular, all the symbolic reasoning in mathematics which is used in the development of physical theories has employed these laws as fundamental. Until rather recently no mathematician or scientist had thought seriously of questioning them. Presumably logicians have for a long time realized that they form the basis only for a *two-valued* logic, that is, one in which all propositions are either true or not-true; putting it alternatively, there are only two qualities associated with a proposition—*affirmative* or *negative*. The existence of a many-valued logic in which propositions may have other values than true or not-true is well established and their properties have been studied.[8] Among other things it

[8] See, for example, C. I. Lewis, *The Monist*, 42: 481, 1932.

turns out that for a many-valued logic the law of duality may cease to have any meaning. This might appear to have only a transient theoretical interest. However, certain mathematicians[4] have tried to see what happens in mathematical reasoning when one excludes the law of duality. An example, given by Brouwer, relates to the problem of the existence of a number k expressing the number of digits in the decimal representation of π at which the sequence 0123456789 begins for the first time. It is not provable that such a number exists; it is not provable that such a number does not exist. Presumably the only course of action with respect to such an example is to continue to carry out the expansion of π. It is at any rate *conceivable* that the sequence will occur somewhere and then the question would be answered. But until this result eventuates, the above conclusion can hardly be avoided if we wish to say anything about the problem at all. Possibly some would be inclined to say that this is precisely what we ought to do, *viz.*, keep silent. But how shall we react to the following paradox of Bertrand Russell: "There exists in a certain village a certain barber who shaves *all* those and *only* those who do not shave themselves. Question: Does he shave himself? The answer is that he neither does nor does not! As far as this village and this barber are concerned the law of the excluded middle has no application. We may object that this village is a decidedly peculiar one, but the fact remains that it and its paradoxical barber are thinkable. Now such considerations might be considered to possess little value for physics. However, it is a fact that recently[5] the proposal has been made that many-valued logics be seriously considered in the further development of theoretical physics. Zwicky's so-called "principle of flexibility of scientific truth," in accordance with which progress in physical research is to be accelerated by uniformly questioning all absolute physical statements, has indeed been shown[6] to have no essential connection with many-valued logics. However, the idea has been put into circulation and will undoubtedly stimulate speculation on the part of those who feel we are too greatly restricted by our customary two-valued logic. In a three-valued logic, for example, the truth values "true" and "not-true" might be replaced by the values "true," "not-true" and "indeterminate." With such a logic there would then be no dilemma with respect to the propositions: the electron is a particle, the electron is not a particle, for now we should admit the third possibility that "it is indeterminate whether the electron is or is not a particle." This might seem to be a trivial way to get out of a difficulty which physicists like Bohr consider so fundamental for physical description. The only point that might be made (of course the above is merely one illustration) is that the adoption of three-valued logic would completely change our attitude towards some of the now apparently puzzling problems and leave us more freedom in the interpretation of new experimental results. Certainly one might conceivably take this attitude: the principle of complementarity viewed now as a fundamental limitation to physical description may actually be a result of our retention of two-valued logic in our reasoning and may disappear as an important physical principle as soon as a three-valued logic

[4] Notably Brouwer, *Zs. f. Mathematik*, 154: 1, 1925.

[5] F. Zwicky, *Phys. Rev.*, 43: 1031, 1933; also E. T. Bell, *Phys. Rev.*, 43: 1033, 1933.

[6] H. Margenau, *Philosophy of Science*, Vol. 1, No. 1, p. 118, 1934.

is adopted. Naturally the question as to how advantageous such a step would be in accelerating physical research and knowledge can only be answered by the reconstruction of theoretical physics, using the mathematical analysis appropriate to the more general logic and the application of it to the newer phenomena. So far as the writer is aware, no serious attempt at this interesting problem has been made

Most physicists will probably be inclined to believe that the possibilities of Aristotelian two-valued logic have not yet been exhausted. The total amount of theoretical physical literature published since the development of classical mechanics is relatively enormous, and it is an interesting speculation to think of how many ideas full of fertility for the developments to come may possibly lie buried in this mass of past "archives." One need only recall how completely Hamilton had worked out the connection between particle motion and wave motion about a hundred years ago—a work which was, so to speak, lying in readiness for its later application in wave mechanics. There will doubtless continue to be new things under the sun in physics, but as always they will continue to evolve out of the old ideas, the permutations and combinations of which are almost numberless.

MODERN SCIENCE, THE HOPE OF CIVILIZATION

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Two persons are gazing at the night sky studded with stars. One is familiar with the facts of astronomy; the other is not. To the one, there is order in that apparent disorder. To the other, the starry sky appears as a chaos. The one knows that only a few thousand stars are visible. The other multiplies these into an uncounted myriad. Modern science, through systematic measurements, has brought order out of that confusion of stars. It can do the same for any apparent chaos of nature or of civilization, if its method and the resulting facts are adequately applied.

In unprosperous times, the muddle of our sociological world is conspicuous But, amid all the endless talk of causes and cures, how often is the simple explanation presented? The cause of our economic chaos is lack of adequate knowledge. If so, the cure becomes obvious. The muddle of civilization has always existed, but modern science possesses the purpose and method which should eliminate the chaos eventually. It has worked wonders in the relatively small portion of civilized activities which it has already invaded. By looking at its material achievements—airplanes, radios and the like—one is likely to conclude that this is a scientific age. But, looking at the sociological world as a whole, one must conclude that this is an unscientific world. While the physical sciences are learning the secrets of atoms and stars, economists, politicians and governments are chipping flints in a Stone Age sociology.

Every person interested in the great currents of civilized progress and in sociological institutions should be interested in the purpose and method of modern science. Extensive understanding means an extensive faith; and this is essential if the necessary social inventions are to be made and applied.

On every hand are found the applications of modern science which contribute to convenience, comfort and other joys of living. You have heard and read many stories of specific achievements of scientific knowledge and you will learn of many more. I could add another story of another success, but I shall speak of modern science, not because it needs spokesmen for itself, but because, in the extension of its purpose and method, lies the hope of civilization.

Modern science is a great movement against the unknown. Its purpose is unchallengeable. It aims to understand by knowing the truth. Its method is uniquely dependable. It is a new kind of strategy which aims to establish the facts, unwarped by such human frailties as prejudice and egoism. The harvest of this movement is tested and testable knowledge, therefore, incontestable knowledge. Any of the major sciences, or uncounted minor ones, is the coordination of facts in a sector of knowledge.

The success of modern science is found not in mind but in method. Great minds are not a monopoly of any single era of civilization. Aristotle possessed one of the great minds, but in accordance with the method of early centuries, he philosophized; he did not experiment. He believed to be true that which appeared to be true. For example, he thought that if two balls of equal size, but of unequal weight, were dropped from a height the heavier

would reach the ground first. He preached what he believed but had not proved. For many centuries that statement was accepted as truth until Galileo tried the experiment. He dropped the two balls from the leaning tower of Pisa and they reached the ground at the same time. This was the real beginning of a systematic accumulation of tested knowledge. The movement of modern science is not without its speculations and theories. But these are tentative and are labeled so. They are accessories after the facts. They are temporary lines of communication to be modified as rapidly as new facts require. The facts always remain supreme in modern science.

No idea or movement—not even a child—has a perfectly definite time or place of birth. Its ultimate beginning is somewhere in the mists of uncertainty. But everything has a practical beginning—a point where it began in earnest. So it is with modern science.

In Europe the Middle Ages were dark indeed. Civilization was struggling in its usual confusion. War and religion were the two outstanding occupations. Eventually, religion celebrated its survival with an intense fervor which built the great cathedrals. But, with all its good intentions, men's minds were more or less shackled by the dominance of man-made precepts, edicts and beliefs. Freedom in thought and action had feebly struggled for centuries. A declaration of independence in these matters was awaiting the next great revolution in civilization. It was a natural result of the great awakening which we term the Renaissance. Ridding their minds of the mists of centuries of philosophical dreaming, thinking men declared that nature could be understood and was worth understanding.

Modern science is just as much a human movement in the midst of humanity as any other movement. It has the same right to a symbol and a shrine as other movements. Born in the late Renaissance, Galileo was the right man, in the right place, at the right time. He was the first outstanding exponent of scientific method wherein is found the irresistible power of modern science. By his achievements in thought and action he gave the first great impetus to the movement which we call modern science—and he symbolizes it so well. To pay him homage, let us transport ourselves to Florence, Italy. Here, amid the tombs and statues, the palaces and art galleries, our imagination revives the human struggles for freedom of expression in all its senses. We seek out a modest church and enter the dim interior. The shadows, reminiscent of the glorious era of the Renaissance, are peopled with the spirits of great men and we remember best the good ones. After a few paces, we find ourselves on a spot that preeminently deserves the glorification of modern civilization. We stand between the tombs of Michelangelo and Galileo. It is impressed upon us that the city which gave the greatest gift to Art also gave the greatest gift to Science. As we stand there with deepening reverence, we note that Michelangelo died the year that Galileo was born. In our imagination we see the failing hand of that superb creator of the beautiful passing the scepter from art to science. In our imagination we hear Michelangelo saying: "The Renaissance artists questioned the old and created the new. They have shown that the world may be beautified superficially. But knowledge alone can supply the understanding which will reveal the third dimension as well. And only perfect and complete understanding can beautify the world through and through."

The substance of that imaginary statement by the old Michelangelo to the young Galileo should be the theme of the

lives of all who are a part of the movement of modern science. It might well be the theme of life for every one, for to understand is a high purpose. Furthermore, understanding, born of incontestable knowledge in all the sciences—physical, biological and sociological—is the only dependable cure for all the ills of ignorance—and this means most, if not all, ills of individuals and of civilization. In reality, or in imagination, all civilized persons should visit that spot in that church in Florence. It is the shrine of modern science. While there, they might pledge themselves to learn to separate incontestable facts from the common confusion of prejudices, assertions, preconceptions, beliefs and even superstitions.

Modern science, with its cold facts and calculating method, is generally supposed to be devoid of beauty and human interest. This is not true. Any science is an array of cold lifeless details; but so is any other structure, even the human being. The parts of a huge locomotive, when strewn on the floor of the factory, are uninteresting. But assemble the parts and put the locomotive into action. Then who will say that it is without beauty and human interest! The greatest masterpiece in painting consists of an array of material facts. The master, while painting it, was building a structure. His method was cold and calculating; every stroke was deliberate.

In the great movement of modern science are found the same intense loyalties, heroisms and sacrifices as in any other movement. Certainly, it is unexcelled in the beauty of its fairness and purpose. Certainly it recognizes no insurmountable barriers. Certainly, it is unlimited by boundaries, for its natural domain is the boundless unknown. All this is expressed in beautiful lines by Tennyson.

> Flower in the crannied wall,
> I pluck you out of the crannies.
> I hold you, root and all, in my hand.
> Little flower—but if I could understand,
> What you are, root and all, and all in all,
> I should know what God and Man is.

Modern science may not reach that far-off goal, but it moves irresistibly toward it.

WHAT'S THE MATTER WITH WHEAT?

By Dr. C. G. WILLIAMS
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When matters go wrong in this country from an agricultural standpoint, it is pretty safe to ask, "What is the matter with wheat?" Wheat troubles are soon communicated to other agricultural products, and, when the farmer begins to slip, other industries will not be far behind. It will be recalled that when our Western congressmen thought that matters were in a bad way for the farmer some ten years ago they brought forward the first McNary-Haugen Bill, which was intended primarily to bring about a better price for wheat. Fortunately, or unfortunately, President Coolidge vetoed this bill.

But wheat was not to be held down for long. Responding to what some have ironically called the "divine law" of supply and demand, it rose decidedly in price and congressmen felt easier for a year or two. Soon, however, other surpluses appeared upon the horizon, and Messrs. McNary and Haugen again forged to the front with another bill, only to be checkmated by the same president, as well as a little later by President Hoover.

Matters drifted for a time, seemingly from bad to worse. The country appeared to be in reverse, moving rapidly in the direction of the bottomless pit. It seemed impossible for those in command to help matters. Realizing that something had to be done and being given the opportunity for action in the national election of 1932, the people of the United States seized it and removed the man at the wheel, somewhat violently, to be sure, and put another in his place. It is perhaps a little early to evaluate this action, but on the whole the people seem willing to try almost anything.

With a newly elected Congress apparently anxious to give the administration a free hand in the solution of the nation's problems, it was not long until the latter came forward with an agricultural program, and occupying a prominent place in this program was wheat.

Why wheat?

There are several reasons why wheat claimed early attention. It is a crop which is grown in every state in the Union and in practically every country on the globe. We have quite authentic statistics from over fifty countries, but as yet none from the planets Venus and Jupiter.

Next to gold, wheat is perhaps our best measure of value. Many people have acquiesced in using wheat as a standard with which to measure or compare other commodities and are wont to say "as good as the wheat."

And wheat has some advantages over gold. It would be more desirable than gold, "yea, than much fine gold," if one were shipwrecked on a desert island. Wheat bread is the all but universal staff of life.

As has been intimated, more people in this country are interested in growing wheat than in any other crop. Probably more people look to wheat, not only as a source of food but as a source of cash with which to pay taxes and to purchase the necessities of life, than to any other one crop.

Accordingly, wheat has got into politics. The wheat farmer is probably more articulate than other farmers. Given a good price for wheat and the world will move forward with very little grumbling, but let wheat get in the dumps and there will be "weeping and gnashing of teeth." Where teeth are lacking they will be furnished by the Farmer's National Holiday Association.

Why is it that the price of wheat has been lower in 1933 than at any time in more than a century? There are several reasons why this is so. One is that the whole world has been enveloped in a great financial depression and has had to tighten its belt in lieu of eating its normal rations. Another has to do with the wheat acreages of the world. What has happened here?

The great wheat-producing countries of the world are Russia, United States, Canada, Argentine and Australia. As an average of the years 1909–13, Russia cultivated 57,430,000 acres of wheat. Of course during the war Russia's acreage dropped very low, but in 1931–32 it rose to 92,070,000 acres, an increase of 60.3 per cent. over the pre-war period.

The wheat acreage in the United States averaged 47,100,000 in 1909–13 and rose to an average of 59,910,000 acres in 1926–30—an increase of 27.2 per cent. The figures for Canada are 9,940,000 acres in 1909–13 and 23,930,000 in 1926–30, an increase of 140.7 per cent. The acreage for Argentine was 16,051,000 in 1909–13 and 19,430,000 in 1926–30, an increase of 21.0 per cent. For Australia the wheat acreage was 7,600,000 in the pre-war period and 14,400,000 in 1926–30, an increase of 89.4 per cent.

These, of course, are the principal wheat-exporting countries of the world. Of some fifty different countries from which quite careful statistics are gath-

ered the average increase in acreage from the pre-war period to 1930–31 is 27 per cent.

In so far as the United States is concerned, there is still another factor that should be mentioned, namely, the decline in the per capita consumption of wheat. This decline dates from the beginning of the present century and amounts to some 20 per cent. It can be accounted for in part by changes in the diet of our people —an increased consumption of fruits and sugar, greater variety in the diet due to refrigerator transportation and cold storage and campaigns for the larger use of vegetables. The per capita consumption of meats has also declined during this period 7 per cent.

As a result of the increased acreage and consequent increased production of wheat, coupled with under-consumption, the world carry-over of wheat has been climbing upward, until in the United States alone it amounted to some 360 million bushels on July 1, 1933. This can only have a depressing effect upon prices.

The foreign market for the wheat crop of the United States is largely a thing of the past. Our exports of wheat in the nineties and in the early part of the twentieth century not infrequently amounted to considerably more than 200 million bushels per year. As an average of the five years immediately preceding the great war they had, however, dropped to 107,103,000 bushels. The war naturally made a great market for wheat and speeded up production wherever this was possible. Our exports for the three highest years of the war period averaged 330,806,000 bushels.

The price per bushel kept pace with this unnatural demand, reaching $2.13 per bushel as an average farm price in 1919. As a result of these abnormal conditions many agricultural prophets felt justified in predicting that this country would never see wheat as low as $1.00 per bushel again.

By 1926–30 our exports had dropped to an average of 174,765,000 bushels. This compares very favorably with our pre-war exports, if one did not know that there was a marked decline of many million bushels each succeeding year, finally dropping to an all-time low of 41 million bushels for the year ending July 1, 1933.

It would seem quite evident that we can not count upon much of an export market for our wheat in the near future at least. Great Britain, our best customer in the past, has been getting about one half of her imported wheat from non-British countries, of which the United States has had its full share, and one half from British colonies. This, however, was prior to the recent Ottawa Conference. If this conference means anything it must mean that Great Britain will in the future get a considerably larger portion of her wheat from the British commonwealth.

Other European countries have used large quantities of our wheat in the past. That market is rapidly disappearing also, The nationalistic spirit is everywhere prevalent; the determination to be as nearly self-supporting as possible has led many European countries to erect tariff barriers which virtually prohibit importations of wheat. These barriers range from 85 cents to $1.60 per bushel, which would seem to mean "keep your wheat at home."

The recent World Wheat Conference in London, in which most of the leading wheat-producing countries took part, attempted to reduce acreages in the wheat-exporting countries, to prevent further increases of acreages in wheat-importing countries and to allot the prospective demand for some 560 million bushels from the importing countries. The allotments were as follows:

Canada	200,000,000	bushels
Argentine	110,000,000	"
Australia	105,000,000	"
Danubian States	54,000,000	"
United States	47,000,000	"

The remainder was divided between Russia, Africa and Turkey. It should be said that Russia was not a party to this agreement. The allotment made to the United States means very little in the matter of providing a market for our normal surplus.

With this situation before it our Federal Government has undertaken to meet it by reducing our acreage to a point where it can be utilized in the main in this country, allowing for a normal carry-over of some 125 million bushels. The great problem was, and is, how to bring about a certain and definite reduction in acreage when nearly 6 million farmers who are scattered from ocean to ocean and from the Great Lakes to the Gulf are involved.

It is a comparatively easy matter for a dozen or more heads of corporations which are manufacturing a given line of products to get together, agree upon allotments and close their factories when their limit is reached. It is quite a different matter for the farmer to close his plant, turn off his principal helpers—his wife and children, by the way—when prices are not to his liking. With taxes and interest to be met, his only recourse seems to be to keep going and take whatever the conditions of the market provide.

Accordingly, the Federal Government has adopted what is known as the domestic allotment plan and has said to the wheat grower: Reduce your average acreage 15 per cent., and we will pay you 28 cents per bushel on 50 per cent. of your average crop for the last three years. This has made it possible for the grower to reduce his acreage without serious loss and has given him assurance that other wheat growers will make the same reduction. The handicap under which the farmer has been working is being lifted to an appreciable extent.

Attention should perhaps be called to some dangers attendant upon such wholesale attempts to adjust crop acreages. The wheat crop of the United States in 1933 was 40 per cent. below the five-year average production of 1926–30, owing to unfavorable weather conditions. What if this should be repeated this year? The answer is that our present abnormal holdover will take care of more than four such low-crop years. There is no immediate danger at any rate. The wide distribution of the wheat crop, both in the United States and in the world, makes anything like a wheat famine very unlikely.

Letting matters take their natural course has brought the farmer, and with him all industry, to a sorry plight. It would seem to be the part of wisdom to take a hand in directing the ship of state. Success to the new men at the helm.

THE SCIENTIFIC JOURNAL, 1665-1730

By SHERMAN B. BARNES
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THE period from the invention of printing to the invention of the learned journal was a period in which the Republic of Letters was handicapped by inadequate facilities of intellectual communication and publicity. In proportion to the increase in authorship and in the multiplication of books the need for communication and cohesion among savants expanded beyond the power of the learned letter, with its defects of privacy, loss of time and irregularity, to fulfil. This need of scholarship combined in the seventeenth century with the rise of the sciences and of intellectual curiosity among the upper classes to produce the learned journal.

The founding of the *Journal des Sçavans* at Paris in January, 1665, was followed by a remarkable expansion of the learned periodical press. Three hundred and thirty periodicals were founded in seven European countries between 1665 and 1730, Germany leading with the publication of 182, Great Britain coming second with 51, and Holland third with 34. In France 30 and in Italy 23 journals were founded. In French Switzerland and in the Scandinavian countries five journals were respectively published. Some contemporaries complained of the confusion caused by the great number of journals, a confusion exploited by the founding of at least six journals which sought to save the time and money of the public by publishing only the best articles taken from other journals. Such predecessors of the modern "Readers' Digest" all said in effect to the public: "Read us, it is not necessary to read others because we give you the best." That the supply of journals outran demand is suggested by the scores of journals of which but one or a few numbers were published. The state was a factor in cutting short the life of many periodicals, especially in France, where the *Journal des Sçavans* alone occupied a privileged position. On the other hand the state prolonged the life of several periodicals, such as the *Acta Eruditorum* and the *Journal des Sçavans*. Other factors that probably contributed to the cessation of many periodicals were financial difficulties, the barrenness of literary output, the absence of sufficiently numerous reading circles to support a periodical, the burden of individual editing, the difficulty of building up correspondence, literary contacts and of obtaining material, the inferior, inaccurate, partisan, polemical quality of many journals which prevented their appealing to public taste, the deaths of editors or publishers and the difficulties of transmission and of circulation.

There is little doubt that the journals were widely read. In 1721 a contemporary remarked that "there is scarcely any literature better received by the public, nor read with more eagerness than that of journalists." Scholars found that journals provided a rapid means of information concerning the existence and nature of new books. Journals functioned as valuable canals of communication on an international scale. Periodicals helped to overcome the difficulty so often referred to in the letters of the seventeenth and eighteenth centuries of procuring books from foreign countries. Poor means of communication and the organization of the book trade on national lines made it difficult to have access to all books pub-

lished. Moreover, journals supplied the public with vernacular accounts of books unintelligible in their original Latin or foreign tongue. This fact is emphasized by the custom followed in many journals of translating even the foreign and Latin titles of books reviewed. A number of periodicals, such as the *Bibliothèque Angloise*, the *Bibliothèque Italique* and the *Bibliothèque Germanique*, were originated to give publicity to the literary productions of some one foreign country.

Among their other functions journals popularized learning. The cultivated gentleman, preferring to learn by conversation in salons, by lectures or by reading short clear summaries of learned subjects, doubtless welcomed the short article and book review of the journal as attractive reading and turned repelled from folio tomes. It became very common for journals to replace books. The large number of worldly men and women who sought to instruct themselves at this epoch found that the reading of a literary-scientific periodical allowed them to speak in the salons of recently published books without purchasing or studying them. This view of the function of the learned journal was widely held at this time. "Journals," declared Denis De Sallo, "have been invented for the relief of those either too indolent or too occupied to read whole books. It is a means of satisfying curiosity and of becoming learned with little trouble." There were at least thirty periodicals in this period which were primarily designed to popularize learning, most of them short-lived, and in addition to these avowed popularizers, all periodicals using the vernacular appealed by their cheapness, convenient formats, brevity, novelty and variety. Moreover, they enabled amateur writers to gratify the desire to see themselves in print and aided the indolent or busy man of affairs interested in science "to whom every great book is a great evil" to acquire a superficial learning. In 1699 a contemporary declared that "by the easy means of journals, which require very little reading, ignorant people speak and decide on everything today, with even more 'hauteur' than scholars."

It is interesting to note that of the 113 specialized journals which appeared in the years 1665–1730, 30 were devoted to natural science. Eighteen of them were general in scope, eleven were essentially medical, and one was devoted to mathematics and physics. In Germany, Holland, Scandinavia and England learned journalism was thus initiated. Moreover, the idea of specialized scientific journalism arose independently in England before the appearance of the *Journal des Sçavans*, since Henry Oldenburg was authorized by an Act of the Council of the Royal Society, March 1, 1664, to publish a scientific periodical as his own private venture. Only his own procrastination robbed Oldenburg of the credit of originating learned journalism. Moreover, Oldenburg may have been acquainted with an unexecuted plan of a weekly or fortnightly scientific periodical specializing in "Physicks, Mathematics, Mechanicks, Opticks, Astronomy, Medicine, Chymistry, Anatomy" extant in Hooke's handwriting in 1663. Only one science magazine appeared in this period in Italy and in Scandinavia, respectively, two in Holland, three in Great Britain, eight in France and fifteen in Germany. Fifteen of these serials were monthlies, five were annuals, one a semi-annual, one a weekly, one a bi-weekly, and the others were too irregular in their intervals of appearance to characterize them. Of the thirty science journals only six were connected with important academies of science. Three of the periodicals connected with academies had the most

continuous existence during this period, the *Philosophical Transactions*, the *Miscellanea Curiosa* and the annual of the Royal Academy of Sciences, founded in 1699. Nine science journals lasted less than a year.

That learned journalism was founded for the convenience of the world of scholars rather than for the general public is suggested by the early vogue of specialized periodicals. While the specialized magazine expanded the content of journalism, from the point of view of the general public the specialized periodical was to some extent a limitation to its participation in cultural movements by the use of magazines. In a word, so it may be argued, specialized journalism attracted certain types of savants, but repelled the public. Yet medical serials had some popular interest because of their publication of remedies for diseases and of their accounts of monstrosities and curiosities; and in an age when religious questions were vital, a wide public was provided for theological journals. And as anatomy and other sciences became more popular, a specialized scientific serial would conceivably have greater appeal, especially since the sciences had not yet become too abstract and complex for easy comprehension. It is also significant that of the thirty natural science periodicals only eight were written in Latin.

It was a characteristic of the science journals that they were composed primarily of original communications rather than of book reviews. The learned journal profoundly influenced authorship through the opportunity it afforded for the publication of short, original articles, discussing discoveries, experiments, observations, etc. The use of periodicals gave authors the advantages of economy, conservation and publicity. Fugitive pieces and short pamphlets on learned subjects were easily lost, causing scholars to withhold publication since "there are but few who have so much time to spare as to write huge volumes, and they know that flying sheets and sixpenny books are as soon lost as printed." Magazines aided authorship by affording cheap channels of publication. Papers would, moreover, be conserved for the benefit of scholars if published in journals. Bayle considered that the most important function of the learned periodical lay in persuading scholars "to make their thoughts public, which otherwise they would conceal in their desks, not wishing to print flying sheets singly." Journals were intermediaries through which a succession of remarks, attacks and replies could be published and noised abroad throughout the learned world. They afforded opportunities for continuous discussion and greater publicity than pamphlets, letters or books. Discoveries which might otherwise have remained unpublished or unknown were given rapid, effective publicity. Moreover, scholars found periodicals helpful as places in which to publish rectifications, denials, corrections, requests for information, documents, data or instruments, and announcements of projects.

By their criticisms and threats of exposing plagiaries, inaccuracies and other defects, by removing scholars from the condition of privacy and isolation, and by the vast panorama of objective learning which journals spread before savants, learned periodicals contributed to the sum total of the critical element in the intellectual life of Europe.

The natural-science journals only very gradually acquired a "critical personality" of their own. Since their content consisted of original papers, the opportunity for editorial comment was limited. Moreover, an ignorant and credulous public influenced many periodicals to publish chimerical and "marvelous" prodigies, monstrosities and wonders. Pierre Bayle once wrote that

journalists "were obliged to speak from time to time of various prodigies and miraculous events, because they learn of the spread of rumors concerning these events and they imagine that the public would complain of their negligence if they said nothing about them." In general, periodical criticism was retarded in this period by poor facilities of intellectual communication and the consequent need for full, impersonal analyses of books, the opposition of authors and learned opinion, which favored objective, impartial description of books without subjective comment, the caution and prudence of editors desirous to avoid offending authors and public, the influence of booksellers upon journals and the power of authority in church and state.

Nevertheless, journalistic "personality" colored several science periodicals. Jean Baptiste-Denis in his *Conferences sur les Sciences* carried on a polemic against the Aristotelian notion of a "faculté pulsifique" as the source of heart movement and of "vegetative souls" as an explanation of the growth of plants. In the *Philosophical Collections* Hooke attacked a method of flying proposed by Francesco Lana, consisting of a ship to be carried aloft by four copper spheres exhausted of air. Hooke argued that Lana did not provide for spheres of sufficient thickness to resist air pressure, unequal on unequal surfaces; therefore, the thickness of the copper used would have to increase in the same proportion to the diameter of the spheres, which would prevent making the spheres proportionately lighter than the air and proportionately strong. Antoine Parent's *Recherches de Physique et de Mathématique* aroused much hostility by its critical reflections. Several editors of science journals gave their periodicals a personal note by utilizing them to promote an "interested" publicity for their books, medicines and lectures. Thus Jean Baptiste-Denis defended and advertised in his *Conferences* a certain "styptic essence" of his invention. Nicholas De Blegny, supported by influential patrons at the court of Louis XIV, founded an Academie de Nouvelles Découvertes, at which public lectures in medicine, anatomy and surgery were given. De Blegny used his *Nouvelles Découvertes sur toutes les parties de la Médecine* (1679–81) to advertise not only the academy and public lectures, but also his books, medicines and office hours "for those who needed him." This periodical was suppressed at the desire of the Paris Medical Faculty in 1682, because De Blegny was an interloper upon its monopoly.

THE PHYSICAL GOETHE

By Dr. JAMES FREDERICK ROGERS

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Goethe was a heroic figure physically, as he was mentally. At twenty "a more magnificent youth never entered the Strasburg gates" and "long before celebrity had fixed all eyes upon him he was likened to an Apollo. Once when he entered a dining room people laid down their knives and forks to stare at the beautiful youth. . . . His features were large and liberally cut, as in the fine, sweeping lines of Greek art. The brow was lofty and massive, and from beneath it shone lustrous brown eyes, their pupils being of almost unexampled size. The short aquiline nose was large, and well cut . . . the chin and jaw boldly proportioned and the head rested on a handsome and muscular neck."[1]

In stature he was rather above the middle size, but, though very erect, he was not really tall, as he was sometimes described. "His frame was strong, muscular, yet sensitive."[2]

From his father Goethe inherited his well-built frame, erect carriage and measured movement and by his mother he was endowed with a large fund of "animal spirits." From neither does he seem to have received much immunity from infection, and, though so healthy from the standpoint of physique, he was, like George Washington, who was similarly endowed, frequently attacked by bacterial diseases. The very abundance of his vitality led him in his younger years to extravagances of physical excess which had much to do with bringing on these attacks of illness.

Already at six years, Goethe was a vigorous specimen. He relates in his autobiography how he was set upon at school by three boys with switches. "Fighting in school time was severely punished, so waiting until the hour for lessons was over I grasped one of my assailants by the hair and hurled him to the ground, pressing my knee on his back; I caught the head of the second, who attacked me behind and nearly throttled him; with a dexterous twist I threw the third flat on the ground. They bit and scratched and kicked, but I knocked their heads together without mercy."[3]

At sixteen he was described as "in the bloom of health," but the student life of the next years was trying even for so robust a being, and at nineteen the round of "restless excitement; irregular living; heavy Merceberg beer; a cold caught when bathing; the unwholesome vapours breathed when etching on steel; perhaps too a chest affection he brought on himself by over-violent exertion; all combined to disturb the sensitive balance of his organization so violently, that one July night he was attacked by a violent hemorrhage. . . . Then a tumor formed on the side of his neck which was troublesome and long in healing."[4] The symptoms have been considered as due to tuberculous infection.

A year and a half later Goethe in a letter wrote, "However sound and strong one may be, in that accursed Leipzig one burns out as fast as a bad torch. Well, well, the poor fox-cub will, little by little, recover." It was uncertain whether or not he had consumption, but a few months later he wrote that "things are looking better."

[1] George Henry Lewes, "Life of Goethe," London, 1864.

[2] *Ibid.*

[3] *Ibid.*

[4] Düntzer, "Life of Goethe," London, 1883.

In December he was "attacked by violent internal pain; all the remedies tried failed to lessen his fearful sufferings. His mother in her utter need tried her old pious plan of opening the Bible with a sharp point. The text to which she opened, 'Thou shalt yet plant vines upon the mountains of Samaria,' filled her with joyous confidence. When the orthodox methods of the pharmacopoeia failed, resort was had to alchemy—a magic salt brought about, or was accompanied by, relief."[5] The pain lasted two days and for three weeks he could not leave his room. A new tumor formed on his neck and finally had to be lanced. But it was Goethe and no ordinary mortal who was sick, and he writes, "I have learned much in illness, that I could have learned nowhere else in life."

For a year and a half he lived a life of invalid seclusion, and in 1771, at twenty-two, he was still troubled with a cough, though in May he was able to dance from two in the afternoon until midnight, "almost without interval." In June he wrote, "I am pretty well in other respects, but one is but half alive when unable to fetch one's breath . . . exercise and fresh air do one good as far as anything does good." It was not many months, however, until he could resume his immense mental and muscular activities. He excelled in all kinds of sports. He was an excellent swordsman and rider. He had a passionate love of swimming, which December's cold could not arrest. He never tired of skating, and "all day long and deep into the night he might be seen whirling along."

"His love of Nature made him indifferent to luxury. . . . In many things he was unlike his nation: notably in his voluntary exposure to two bright wholesome things, which to his contemporaries were little less than bugbears—fresh air and cold water."[6] When rebuilding his Gartenhouse he lived in it or about it. "Wrapped up in my blue cloak, I laid myself on a dry corner of the veranda terrace and slept amid thunder, lightning and rain so gloriously that my bed was afterwards quite disagreeable."

The daily program of his young manhood is thus described by Lewes. "He rose at seven, sometimes earlier, after a sound and prolonged sleep; for like Thorwaldson, he had a 'talent for sleeping' only surpassed by his talent for continuous work. 'Till eleven he worked without interruption. A cup of chocolate was then brought and he resumed work till one. At two he dined. This meal was the important one of the day. His appetite was immense. Even on days when he was not hungry, he ate much more than most men. Puddings, sweets and cakes were always welcome. He sat a long while over his wine, chatting gayly to some friend or other. . . . He was fond of wine and drank daily his two or three bottles. This was, for a Rhinelander, a moderate amount, to which he became accustomed from childhood. The quantity he drank never did more than exhilarate him; never made him unfit for work or for society."[7] He later reduced his ration of wine and "often took neither wine nor punch."

By the time he reached forty the desserts had disappeared from his table and "even the customary coffee after dinner. His mode of living was extremely simple. Between eight and nine a frugal supper was laid, but he never ate anything except a little salad or preserves. By ten he was usually in bed."[8]

His was the temper of the wide-seeing philosopher which he was, and he once remarked, "You see how far I am from hypochondriac disquietude which sets so many men at variance with their places in life."

[5] *Ibid.*

[6] Lewes, *op. cit.*

[7] *Ibid.*

[8] *Ibid.*

He had some attacks of severe illness subsequent to the one described. At forty-six he was tormented by a swelling in the cheek, which with the means resorted to for cure affected his sensitive nervous system greatly, "yet he laboured without ceasing." A few years later he had "a violent and protracted cold, followed by erysipelas, a convulsive cough and difficult breathing." Two years later he was kept indoors for a considerable time with another violent cold. At fifty-six he was "very ill indeed with colic of the kidney," of which he had three attacks in as many months.[9]

Every two or three years one or other of these ailments returned to the attack, but Goethe did not allow his sufferings to interfere greatly with his work and his splendid constitution reacted for health between times

"At seventy he was younger than many men at fifty" and at this age he was described as "of high stature, of strong robust build, the brownish hair slightly bleached, the brow high arched, the eyes still fresh and fiery, his complexion white and red. The features of the countenance were strong, the chin somewhat prominent, the neck considerably fleshy."[10]

"As a rule he rose at six o'clock, and partook of coffee immediately. At seven he summoned his secretary and dictated until eight, sometimes until half-past eight. Then he walked on the terraces or in the garden until half-past nine; then breakfasted. After breakfast he dictated again or went down into the garden, where he remained until half-past five, when he ate some white French bread and drank some wine. After that he stayed in his room or, in fine weather, paced up and down the gardens repeatedly. Sokell never found him seated when in the gardens. In the evenings he read the letters that had come and signed those that he had dictated during the day. He went to bed at nine or half-past nine and enjoyed deep and sweet sleep. . . . He was very temperate, and ate and drank by rule, and during all the time in Dörnburg enjoyed perfect health."[11]

"There was abundant life in the old Jupiter whose frame was still massive and erect; whose brow had scarcely a wrinkle of old age; whose head was still as free from baldness as ever. . . . Hufeland, the physician, who had made a special study of the human organization with reference to its powers of vitality, says that never did he meet with a man in whom bodily and mental organization were so perfect as in Goethe Not only was the prodigious strength of vitality remarkable in him, but equally so the perfect *balance* of functions . . . no function was predominant, all worked together for the continuance of a marvellous balance."[12]

At eighty, "the old man showed unmistakably that he was old. His hearing became noticeably impaired . . . yet his eyesight remained strong and his appetite good . . . he presented a striking contrast to the earlier years, in his preference for closed rooms. The heated and impure atmosphere of an unventilated room was to him so agreeable that it was difficult to persuade him to have a window open for the purpose of ventilation. . . . he sat in rooms so heated that he was constantly taking cold."[13]

Yet still he toiled and after eighty he produced some important works. In his last years he led a very regular and secluded life, and he passed away in his chair at the age of eighty-three.

[9] Düntzer, *op. cit.*
[10] Lewes, *op. cit.*
[11] Düntzer, *op. cit.*
[12] Lewes, *op. cit.*
[13] *Ibid.*

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

COLOR CHANGES IN ANIMALS

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THE ability possessed by several groups of animals to change their general body coloration and alter their color patterns has excited the interest of professional zoologists and nature students alike for many years. Almost every one knows about the chameleon and its many colors changing with fair rapidity from one shade to another in response to background color or nervous excitement. The true chameleon is a native of Africa and India and is seldom seen in this country, but in Florida the so-called chameleon, Anolis, is a fairly common color-changer well known to tourists.

When we look through the animal kingdom for this remarkable response, we find that many animals are unable to change their color even though their skin contains an abundance of coloring matter or pigment as it is called. Pigment of one color or another is found in every major group of animals, but only in a few of the higher groups of invertebrates and in the lower groups of vertebrates is this pigment mobile and controllable. For example, among the mollusks (which include clams, oysters, snails, slugs and squids) there may be no color changes at all, as in clams and oysters; or extremely slow color changes, as in snails and slugs; or extremely rapid color changes in the squid and octopus where the colors flash from one shade to another in rapid succession in response to nervous activity. Many crustaceans, such as shrimps, are able to adapt themselves by changing color in such a way that they become pale and transparent over a white background, very dark over a black background, and variously colored when over colored backgrounds. The process of adaptation may require from several minutes to an hour, but when completed there is a remarkable approximation to the background shade and color so that the animal blends with its surroundings and is made less conspicuous than other animals which do not have adaptive color control.

Among the vertebrates or backboned animals many of the fishes, amphibians and reptiles show responses to background color and pattern. The common flounder will not only approximate the color of the background on which it lies, but will cause its skin to be mottled with spots and patches of color to simulate those of the background. In the laboratory, flatfishes placed over a black and white checkerboard pattern will cause their body pigment to change in such a way that a rough checkerboard arrangement of light and dark areas will be produced. Among the amphibians the frogs are well able to change their bodily color from a pale yellowish green to a deep brownish black, depending upon the shade of the background. Several reptiles in addition to the chameleon also are able to bring about adaptive color changes, the horned toad (which is not a toad at all, but a true reptile found in the southwestern part of the United States) has been used as a subject for color-change studies because of its readily controllable color changes.

If we take a piece of the skin of any of these animals and examine it under the microscope we find that the pigment,

instead of being diffused or simply deposited in ordinary skin cells, is contained within special cells called chromatophores and these chromatophores are able to contract or expand under the control of the animal. When a chromatophore is contracted the pigment is reduced to a minute spherical mass, and when the chromatophore is expanded the pigment is spread out into branching cell processes which may interlock with neighboring processes of other chromatophores to form a network. In this condition the animal takes on the color of the pigment network.

Further examination shows us that usually there are several kinds of chromatophores in the same animal. Some contain black pigment, some red, some yellow, and there may be other colors. Then, too, there may be a layer of pigmented cells which is iridescent and diffracts and reflects various colors as does an oil film on water.

In the vertebrates varying shades and colors are produced by the degree of contraction and expansion of the chromatophores, by the contraction of an outer layer of color cells revealing a layer of expanded color cells beneath, by light reflecting from the immovable iridescent cells, or by all the pigment cells reflecting the light to produce a blended color. In the invertebrates there is usually only a single layer of color cells but these are of different colors; red, yellow, brown and black being commonest. In the crustaceans and mollusks a yellow color, for example, is produced by an expansion of the yellow cells and a contraction of all the others; red or brown body color indicates that the chromatophores containing these pigments are expanded to a maximum and the other colors are reduced to scattered points—mere specks of color which do not affect the general hue.

The squids are peculiar in that they produce their rapid color changes by a somewhat different means than do all the other color-changing animals. Here, pigment is contained in elastic sacs to which are attached many small muscles. When the muscles contract this sac is spread out over a large area and the pigment presents a large surface; when the muscles relax, the sac contracts to an inconspicuous spot. By rapid nerve action on these muscles the squid causes a symphony of color to be played on its skin, produced by a "color organ" evolved long before man himself appeared on the earth.

All these facts have been known to naturalists for a long time. Within recent years studies have been made on the inner mechanism which controls the movement of pigment, and these studies have led to some very interesting and important conclusions.

Early experiments on the controlling mechanism in color change activity indicated that the nervous system played an important part in bringing about the movement of chromatophores and, in fact, stained sections of these color cells frequently revealed nerves in actual contact with them. Furthermore, when a living nerve was stimulated artificially, chromatophore movements could be produced. So the general assumption was made that color changes are directly under the control of the nervous system. This conclusion seemed obvious in view of the fact that the animal's eyes are necessary for ordinary pigment movements.

More recently, however, we have been hearing much concerning control of vital processes by means of hormones, or humoral substances, which are secretions of certain tissues of the body that are carried in the blood and other body fluids. These substances have the power to control a great variety of bodily functions independently of, as well as in conjunction with the nervous system. We know a great deal concerning the secretion of the adrenal glands, and of the secretion of the pituitary gland, and of

the thyroid and the pancreas. New secretions and new effects are being discovered until it would seem that hormones are being produced for some specific purpose in nearly every tissue of the body.

So it was not surprising to find that chromatophores are caused to contract or expand under the influence of hormones—the same hormones in many cases that influence other bodily processes. If we inject adrenalin into the blood stream of a fish or a frog or a chameleon its chromatophores contract; inject pituitrin and they expand. Remove the pituitary gland from a fish and its pigment cells contract and remain so until more pituitary secretion is admitted to the blood stream, because the pituitary produces the substance that controls expansion; remove the adrenal gland and no more contraction by means of the adrenal hormone is possible.

When nerves leading to the chromatophores are cut, and when hormones are no longer allowed to come into contact with the chromatophores, they still may be induced to contract or expand by changes in light intensity or temperature. Certain drugs will also cause pigment movement under laboratory conditions.

One of the most unusual instances of hormone control was announced five years ago, when it was found that the stalked eyes of crustaceans contain a substance which, when liberated into the blood stream, causes the chromatophores of the crustacean to contract. In these animals, of which the shrimp is an example, the nervous system plays no part in color-change activity, so the control is entirely humoral. An extract of the eyestalks can be prepared which will cause chromatophore contraction in the living animal or in isolated pieces of skin containing chromatophores. When the eyes are removed, the chromatophores expand, because no more contraction substance can be produced.

More recently the eye-extract has been injected into other animals which change color to see what the range of effectiveness of this new hormone might be. Injected into fishes it produced contraction of chromatophores, and, rather amazingly, produced expansion of the color cells when injected into frog tadpoles.

The interesting thing about these discoveries and experiments, in addition to solving some of the problems of animal color changes, is the fact that additional evidence is presented for the presence of well-developed hormone-producing structures among the lower animals. These structures make up what is called the endocrine system—a system of coordinating organs in the vertebrates as important as the nervous system in controlling vital processes. Within the last year Dr. G H. Parker, of Harvard, has found that nerves themselves secrete a humoral substance which passes to the affected organ and sets it into operation. So it may very well be that all bodily control is ultimately humoral.

The endocrine system is highly developed and found extensively among the vertebrates, but until recently its presence was only suspected in the invertebrates. As yet very few endocrine substances are known among the invertebrates—the crustacean eye-hormone being by far the most spectacular. And, too, the fact that an invertebrate hormone is effective on vertebrate structures seems highly significant. The occurrence of such a substance in crustaceans which will produce color changes in fishes and amphibians points to a forerunner, in the evolutionary history of animals, of the more highly developed vertebrate endocrine system.

FRIENDLY GERMS

By Dr. W. LEE LEWIS
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THE words used in human speech are an interesting study in themselves. If I use the word "taste," in the sense of an appreciation of cultural things, you think at once only of good taste. And yet some wag very properly remarked of some one that, "He had lots of taste, only it was bad." "Luck" invariably implies good luck; as we say one is "out of luck," meaning things are going badly. "Smells" suggest bad odor, yet most flowers smell nice. And so when I say germs you at once think only of small, repulsive wigglers, invisible to the unaided eye, that bode no good for mankind.

In the case of germs or bacteria there is a reason for this first reaction that all germs are bad. Bacteria like the same foods that we like, and so we are eternally in competition with them to keep our foods from spoiling. We boil alive these small competitors of ours, we freeze them, we deprive them of their drinking water, and dose them with chemicals in perpetual dispute over the ownership of foodstuffs. Bacteria also attack us in person and give us diseases. In spite of all we have learned about them they persist surprisingly. Bacteria were the first settlers on this earth, antedating us by a few million years. They have been called our younger brothers. They are really our very great-grandparents. Small wonder they know how to survive with such long and varied experience behind them. In spite of all that the microscopes and the laboratory have revealed about them, there are probably as many germs to-day in kind and numbers as there ever were.

My purpose for the moment is to break a lance in behalf of the friendly germs, for there are good germs as well as bad germs. We have gained our impression of the invisible bacterial population about us, much as some future historian might judge our contemporary human population from a stack of current newspapers. The vicious members of the respective groups find the most publicity.

When you can not overcome a supposed enemy, the next best thing is to ally with him or merge, as we say in business. And so, as our knowledge of bacteria, their habits, diets, end products and life cycles, has grown, we have increasingly harnessed these brownie chemists to serve our purposes.

In their important service to man I would mention first the large group of bacteria that live in the soil and the water and destroy dead organic matter. These are the great public scavengers who seize upon the waste matter of civilization and resolve it into simpler forms. These simpler forms may be utilized as plant foods and so enter again the cycle of living things. As plants they become food for animals and reach their highest spiritual and intellectual expression in man. The life of a chemical element is just one great merry-go-round after another.

Consider the element nitrogen, present in all life forms from the cell of an amoeba to the brain of a great artist. First, nitrogen is combined as an inert salt called nitrate. Plant life utilizes nitrogen in this form and builds plant protein out of it. Animals eat plants and build their protein from plant protein. The operation is wasteful and all along the way these friendly bacteria of nature convert the waste nitrogen compounds back into nitrates where plants may again start them on the highroad of life.

With the growth of population it has become increasingly impossible to dis-

pose of domestic and industrial waste through natural waters and the soil. Sanitary engineers have accordingly taken a page from nature's book and utilized these bacterial scavengers in great municipal sewage disposal plants. Moreover, as is so often the case when man borrows an idea from nature, he improves upon it. And so the resolving processes carried out by nature on waste matter by friendly germs are made more efficient both as to time and space in modern city sewage plants.

Another interesting illustration of how these friendly germs respond to sympathetic cooperation is found in the legumes, that is, such plants as beans, alfalfa and clover. On the roots of these plants may be found little pellet-like nodules. These are the houses for friendly germs. They are accommodatingly supplied by the plant without injury to itself. The bacteria which dwell there in a happy cooperation with the plant catch the free gaseous nitrogen of the air and build it into nitrate which is basic plant food. That is why clover-like plants are grown and plowed under to enrich the soil. That is why the U. S. Department of Agriculture once distributed these little root bacteria to farmers to place on their clover seed for soil enrichment.

I need to mention the use of bacteria in healing the ills of humanity. Formerly the death rate from diphtheria, for example, was very high. Now, if taken in time, the antitoxin treatment is practically a certain cure. How is the antitoxin made? Diphtheria bacteria in the laboratory are set against diphtheria bacteria in the throat. They are grown in large quantity in a kind of broth. They are then filtered and the resulting solution of toxins injected into the blood system of a horse. Later the antitoxins thus formed in the horse are injected into the blood of the diphtheria patient to help him neutralize and overcome the toxins from the marauding diphtheria germs in his throat.

This is but one example of many antitoxins and sera that are to-day saving countless human lives. Thus under certain circumstances enemy germs may become friendly germs.

In the realm of foods, bacteria are used extensively. For example, in the dairy industry butter owes its delicate, pleasing flavor to bacteria which bring about subtle changes in the butter fat. Special sour milks, much prized by many persons, are made with pure cultures of certain bacteria. These special sour milk germs are believed to attack and overcome certain hitch-hikers in our alimentary tracts that occasionally commit improprieties. Cheeses depend upon bacteria for their special flavors. The high cheeses are largely predigested in this manner. Soy-bean sauce is made by a fermentative process involving germs.

The farmer chops green stock feed into his silo and lets the bacteria ferment it. It is a rich, appetizing and nutritious feed for live stock. Sauerkraut is distinctly a product fermented by bacteria from cabbage. Vinegar is made by a germ of questionable taste. Bacteria play a strong part in the curing of meats. Cured meats are placed in a sweet pickle for several weeks where bacteria serve in many ways to develop that unique flavor we all like in smoked ham and bacon.

Salt-rising bread involves the action of germs rather than the usual yeasts.

In other industries, such as the tanning of leather, the manufacture of certain commercial solvents, the preparation of rubber, tea, tobacco, indigo and cocoa, and the preparation of flax, hemp and jute, bacteria are pressed into the service of man.

Germs may even be used in the mining business, for it has been found that they can convert native zinc ores into soluble form by oxidizing the natural sulphide ore into soluble sulphate of zinc.

Germs may eventually be used to heat houses. This comes about from the fact that some germs like a good tropical

temperature, around 80° C. They are the real Californians and Floridans of the bacterial population. However, there is this difference, that, whereas the Californians and Floridans are reputed to have difficulty at times in controlling their respective climates, the heat-loving bacteria settle the matter by manufacturing their own climate. They attack the material in which they find themselves and break it down in such a manner as to produce heat. Thus, given a proper food material, they could produce enough heat for themselves and allow us to bask in the overflow.

How is it possible for a tiny subvisible organism like a germ to produce effects which are noticeable to a being so much larger, in fact billions of times larger than the germ itself?

Germs are so small that scores of them could dance on the point of a needle at the same time, and in fact often do.

There are many reasons why they can make such deep-seated changes in such large amounts of matter, but the reason most often neglected is a simple one. It is this: Their stomachs are all outside them instead of enclosed in their bodies, as is the case with higher organisms. In other words, if we eat a bowl of soup it is conducted to our stomach *via* the esophagus. We send out various ferments such as pepsin into this transferred soup to digest it. But we only digest that amount which we swallowed and which we will assimilate.

But suppose we drop a germ in a bowl of otherwise sterile soup. The volume of soup is tremendous in proportion to the volume of the germ. And yet the germ will send out digestive ferments into the soup which surrounds him. He will grow large on the soup so digested and absorbed. Finally he will divide into two germs like his former self only smaller. They in turn will each split by simple cell division into two more young germs. And so the process goes merrily on.

Eventually the soup will all be predigested from the germs' standpoint and all spoiled from our standpoint.

Thus it is that a germ digests for its own energy and building purposes an amount of food matter far in excess of its own body needs. Thus it is that a germ's stomach is all outside him, where a higher animal's stomach is inside him and so limited in the amount of food material it can transform.

The rapid multiplication of bacteria by simple cell division and their tremendous digestive capacity are the two principle reasons for their great power to transform matter.

Summarizing, then, I have tried to prove that just because he is a germ does not necessarily prove that he is bad. Many are benign and friendly to man and some of the so-called bad ones have been trained to defend us against their outlaw brothers.

They are public scavengers and employees of many an industry. They respond to the slightest sympathetic understanding and cooperation. They work night and day without pay. They demand neither sleep nor vacations and are fiercely energetic.

Men and germs have been long together on this earth and are growing to understand each other better every day. Who knows but some day they will be no longer enemies and little children will prattle kindly:

> I love to see a little germ
> And pat him on the head,
> So prettily he wags his tail
> Whenever he is fed.

MOSSES

By Dr. A. J. GROUT
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To the great majority of people, mosses will suggest two things, "moss-back," and the proverb, "Rolling stones gather no moss." People are continually asking me, "Of what use are mosses?" We can neither eat nor wear them, but certain kinds have been used to stuff beds on which to sleep. While mosses have some very practical uses, as we shall see later, one of their main values to humanity is an esthetic one. If mosses were suddenly removed from the landscape, people would wonder what was the matter, without being able to give an explanation as to why it had so suddenly become bleak and uninteresting.

Let us listen to what a famous poet, who wrote mostly in prose, has to say of mosses, "Veiling with hushed softness the dintless rocks, covering with strange and tended honor the scarred disgrace of ruin—to them, slow-fingered, constant-hearted, is entrusted the weaving of the dark eternal tapestries of the hills."

The freshness which delights the eye after a summer shower is in a large measure due to the magic transformation of dried-up brown mats of moss into cushions of living green. Some parched and scorching summer day get a mat of this brown, dry, dead-looking moss from a ledge or boulder, moisten it, and behold a resurrection such as happens with every passing shower.

Mosses are all small plants, for they have no vascular system for conveying liquids from the earth to the stems and leaves. Neither have they any true roots for absorbing moisture and minerals, hence they are condemned to be perpetual dwarfs, shriveling at the touch of the sun and reviving with the raindrops; but having a vitality and endurance so that they will grow on the bare rock or boulder or ledge, even in the arid mountains of the west, often so dry they will crumble to powder at the touch, yet springing to life and vigor with every rainfall. In many cases the powder of the crumbled plant, if moistened for a time, will sprout out into fresh new life. Some of these drought-enduring plants have become so hardened to the lack of moisture that they have retained their vitality on the herbarium shelves of the museum for several years and have started to grow when moistened.

The length of time which the spores of these mosses can survive has been tested, and one authority reports that spores seventy years old have germinated. This, however, is subject to doubt, but it seems probable they will live for at least a quarter of this time.

Young capsules with developed spores are rich in protoplasmic content. The young capsules of the hair-caps taste like the blood from a bitten tongue and doubtless contain a high percentage of nutrition. If I were starving in a wilderness where these capsules are found, I should certainly try eating them, either raw or in a soup, even though no one knows by experience what the after-effects might be.

More than once mice have raided my duplicates and eaten the spore-filled capsules. Mosses in the field are often found with many capsules eaten by insects or mice. However, mosses as a class are remarkably free from parasitic fungi or animal foes.

Many species have most delicate and ingenious devices for retaining moisture. The leaves of most mosses, especially those of moist habitat, are but one cell thick, but those of dry rocks and ledges

often develop a double layer of extremely thick-walled cells in the upper portion. This is to prevent evaporation.

In most mosses the lower leaf cells are large and thin-walled for absorption, especially those cells at the leaf angles of certain species, which look, under the microscope, like tiny bubbles. When it rains the mosses spread out their leaves to catch the moisture in their cuplike bases, where it is absorbed into the large thin-walled cells. As the weather dries them up, the leaves close up tightly to retain moisture within. The arrangement of leaves, like the shingles on a roof, also assists to keep in the previous moisture.

One of the most important economic services of mosses is due to this very power to absorb and retain moisture. The forests are given the credit for retaining moisture, preventing floods and keeping up a steady flow of water in the streams, but a very large part of the water-conserving power of the forests is due to the mosses which grow in the shade of the trees In our climate the moist atmosphere of the forest shade is necessary for vigorous moss growth, but in the treeless mountains of England and Scotland the atmosphere is so moist that the mosses grow freely without shade.

The most efficient of these water-conserving mosses is *Sphagnum*, or peat moss. Its leaves are made like tiny sponges, most of the cells of leaf and stem being hollow with open pores. By accurate test, dry peat moss will absorb twelve to fifteen times its own weight of water. This makes some of the most absorbent species of peat moss one of the very best dressings for wounds. It not only absorbs wound drainage and pus but has an antiseptic action also. Because of these properties of absorption and antisepsis, peat moss is also very useful as a stable bedding, preserving all liquid fertilizer and preventing stable odors; also in packing the roots of plants for transportation. Live fish may be carried for long distances packed in this moss.

Peat moss and embedded vegetation in favorable locations, such as the Scottish mountains, form layers from three to twenty feet thick and in bogs formed from filling in small lakes, the peat is of unknown depths. Into these bogs plunge animals and men in hurried flight or by accident. Not only animals, but persons are preserved as fossils by its antiseptic power. Dana reports the finding in recent times in English peat bogs of horses and knights in armor of the period of the Wars of the Roses and in a most remarkable state of preservation. In another bog bodies of men dressed in haircloth of a prehistoric period were uncovered.

These bogs are more treacherous than quicksand and even to-day many persons perish in them. If you find yourself sinking in one of these bogs where there is no help and no escape for you, console yourself with the fact that in the far distant future you will make a most valuable museum specimen. Peat, when the firm part of the bog is cut in slabs and dried, makes a most delightful fuel, both as to heating efficiency and pleasing odor. Quantities of peat have been dug out of nearly every subway excavated in New York City.

Aside from the uses of peat above mentioned, and the water-conserving action of mosses, they also serve directly to prevent erosion and to aid soil accumulation. On the bare earth in the Carolina mountains, where vegetation has been removed by man or nature, one may frequently see lilliputian mesas formed by a matting of moss protonema which has held together the particles of earth when struck by the falling torrents of the summer showers.

The stones in the beds of our New England brooks are often covered with masses of sand and gravel, caught and held by the mosses which cover them.

The bare bones of our New England mountains have become gradually covered by mosses and lichens, which slowly creep inwards from the margin of ledges until they are covered with a thin layer of vegetation. Then ferns, grasses and other herbs follow. As the mat thickens shrubs spring up, and finally mighty spruces and pines which have only a foot or so of soil to sustain them. When a tornado topples these trees, one can see how little they had on which to subsist. Let fire spread through such a region, as has happened in the Adirondacks in recent years, and the soil itself burns, leaving stark and naked the skeleton of the landscape and destroying nature's patient handiwork of a million years. Meditate on this, you who carelessly flick cigarettes or leave unquenched picnic fires on our beautiful mountain sides.

Now that we have learned something of the part mosses play in nature and in human affairs, let us consider them from a botanical point of view. What are these mosses which we are to consider? Not the so-called sea mosses—they are marine algae, a much lower order of plant life. No true moss will grow in salt water or salt marsh. Not the ghostly Spanish moss of southern forests —that produces flowers and seeds. Not the long, pendant, gray mosses of northern forests—these are lichens, also a much lower order of plant life.

Mosses are small plants varying from one sixteenth of an inch to rarely eighteen inches in height. They consist of stems, bearing so-called leaves, which perform the functions of leaves, although they do not correspond to the leaves of the higher plants. These leaves, having abundant chlorophyl, are in most cases but one cell thick.

Mosses are spore plants, producing tiny one-celled spores instead of seeds, but they have very distinct sex organs. A single plant may be bisexual, like the rose or lily, or unisexual, as in the willow or most of the higher animals. Moss spores are borne in little pods called capsules, which are usually on a short stalk. In nearly all cases these capsules open with a little lid. Very often there is a long beak, like a handle, which aids in lifting the lid when the spores are ripe. Sometimes this beak may be nearly as long as the capsule itself, and a raindrop or a beetle can easily knock it off. Underneath this lid, around the mouth of the open capsule, is a tiny fringe, called the peristome, which aids in the distribution of spores. Microscopically, this is one of the most interesting structures to be found in nature, and the teeth of which the fringe is composed are often sculptured with intricate designs and beautifully colored, deep red or dark purple.

When moist, this fringe closes much like the flowers in the dandelion head and keeps the spores dry, and also prevents them from being deposited in a lump. As the peristome dries, it opens so that a passing breeze, the foot of an insect, or any other passing object may scatter the spores into the air. Some of the peristomes twist up like a rope in order to close, others simply fold up until they form a compact closed cone. Still others have an inner peristome with holes, and an outer row of teeth folds over these holes and closes them.

Mosses preceded the arrival of flowering plants by untold ages, yet they had developed much the same devices for spore distribution that flower-lovers know so well as the means of the distribution of pollen. Pollen, as the botanists tell us, is only a spore that has gone a little way on its development.

The capsules of peat mosses burst when dried by the sun, sending out a tiny cloud of spores several inches into the passing breeze, accompanied by a whispered but distinctly audible "pop." This is easily demonstrated by collecting

the peat moss when its capsules are ripe and placing it near a fire or in the sunshine.

A very common moss in New England has capsules which look like a grain of wheat with a little tube on one end. When the lid falls off it leaves this little tube like the mouth of a blowgun. When a beetle or a mouse steps on the capsule the spores are shot out onto its coat and are carried away to be scattered here and there.

Mosses of the *Splachnum* family have developed low tastes, catering to flies, much like the stinkhorn fungi and the carrion flower. These mosses grow only on dung or decaying animal matter. Below the spore cases some species spread out a bright-colored purplish or yellowish umbrella. This umbrella also secretes a carrion odor, which, in connection with the color, causes the flies to visit it and carry away the sticky spores. Other members of this family give off a secretion at the base of the capsule, which flies eagerly lap up.

The spores of the water moss, *Fontinalis,* are sifted through a trellis-like peristome to be carried away in the current. It is to be noted that with the exception of these two families the moss spores are dry and powdery like the pollen of wind-pollinated flowers.

Thus, as in the distribution of pollen, wind, water, animal and explosive force are used for distribution of moss spores and in the *Splachnum* family we have color, odor and something like nectar for attracting insects. It will also be noted that the foul odor of the animal matter induces the insects to carry the spores where they will develop. Flies have been observed to go directly from *Splachnum* capsules to fresh cow dung.

On moist soil, bark or rotten wood or even on moist rocks, the microscopic spores develop tiny green threads called protonema, which are very much like fresh-water algae. One may often see the soil in greenhouses and old fields covered with this green network. From these green threads arise leafy buds which become moss plants, thus completing the life cycle.

For one with imagination there is adventure and romance in moss study. The species new to North America collected at the summit of the North Carolina mountains; the rare species from the continental divide in Colorado; the mosses collected in northern Alaska by the botanist Frederick Funston long before the time he collected in Aguinaldo in the tropical Philippines; the mosses collected in the arctic wastes by Admiral Peary on his way to the North Pole; the memories associated with mosses collected from the tropical jungles of the Florida Everglades and in the mysterious wastes of the great Dismal Swamp, all these have the power to thrill the moss-lover.

Like an affection for the birds, the trees, the flowers, the rocks and the stars, an interest in mosses furnishes an incentive to out-of-door life and healthful recreation, inexpensive, free to all country dwellers and travelers, available at all seasons, in winter's snows or summer's heat.

RESEARCH IN THE BUREAU OF DAIRY INDUSTRY

By O. E. REED

CHIEF, BUREAU OF DAIRY INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

WE have heard that "agriculture is a basic industry" for so long that the full significance of the phrase was all but lost in its own reverberations until the depression disrupted economic stability throughout the world and seriously threatened standards of living everywhere.

Now the people of the United States are again coming to realize the basic importance of agriculture in our national welfare and its close relationship to their own individual prosperity. They now understand more fully why there can be no general national prosperity without a prosperous agriculture; such understanding forecasts a more intelligent support of our Federal and State agricultural research institutions by a united people seeking their own economic security. Our Government is wisely attempting to bring us out of the depression by "tailing up" the agricultural industry with the emergency powers of the new Farm Act, but the weakened "critter" will need the nutritious food of scientific research to keep it on its feet and to give it strength to weather future crises.

Scientific research has been of immeasurable value to every branch of agriculture in the past; from now on it will be needed more than ever, particularly in helping to meet inevitable adjustments in the changing and competing markets of the world. It is not enough merely to adjust the amount of production to the needs of the consumer; we must adjust other factors as well. Producing quality products, transporting and storing them to retain that quality, developing new kinds of products for specific markets and cutting the cost of production all along the line are problems and opportunities for agricultural science.

No field of agricultural research offers greater problems of beneficial results for all of us than dairy research—research which contributes to the development of a sound and prosperous dairy industry. Nutrition specialists have demonstrated that there can be no substitute for dairy products in our national diet if we are to obtain the maximum results in health and to perpetuate a virile race through properly nourished children. Furthermore, it is imperative from the standpoint of national prosperity that we build a sound and prosperous dairy industry, for dairy farming comprises the largest single branch of the agricultural industry. On 70 per cent. of the farms of the United States will be found one or more milk cows, turning the products of the soil into milk and cream for sale or for use on the farm. The nation's 25,000,000 dairy cows account for nearly one fourth of the total income received by farmers for the sale of farm products, an income that has a wonderful stabilizing effect on agriculture because it is more or less steady throughout the entire year. More than that, the dairy industry through its numerous branches provides a means of livelihood for countless numbers of people who are not on farms. It provides jobs and income for men who truck the milk to the creamery, for great numbers of men in dairy plants who make butter and cheese and

ice cream, for men who work in the condenseries, for others who bottle and distribute milk to city doorsteps, for men who load tubs of butter and cans of milk on trains and on ships.

In an effort to develop and establish a satisfactory dairy industry in the United States the Federal Bureau of Dairy Industry is engaged in a program of scientific research designed to bring about three principal results: (1) Greater efficiency and economy in the production of milk and in the manufacture of its products; (2) improvement in the quality of milk and cream on the farm and of dairy products in the factory; and (3) a wider utilization of dairy by-products. The successful attainment of these three results should go a long way toward lowering the cost of dairy production, increasing the consumption of dairy products, and increasing the prosperity of the dairy farmer, the manufacturer, and the distributor, and at the same time provide a greater portion of our people with dairy foods that are wholesome and economical.

The unit of production in the dairy industry, of course, is the cow; and much of our research has been directed toward improving her efficiency as a milk-making machine. We know from our study of thousands of records of milk production and cost of feed that the high-producing cow is the most profitable cow. She may eat more feed than a lower-producing cow but she returns more income per dollars' worth of feed. In 1931, for example, in dairy-herd improvement association herds on farms where butterfat was sold for 30 cents a pound, a cow that produced but 100 pounds of butterfat a year did not return enough to pay for her feed. But the cow that produced 150 pounds of butterfat returned enough to pay for her feed and $8 in addition. The cow that produced 300 pounds returned $38 in addition to her feed cost, or almost 5 times as much in income over cost of feed as the cow that produced only half as much butterfat. The cow that produced 500 pounds of butterfat returned $82 in addition to her feed cost, or more than 10 times as much income over feed cost as the cow that produced 150 pounds.

But the average dairy cow in the United States produces only about 180 pounds of butterfat in a year. Obviously then a great many of the 25,000,000 dairy cows in the country to-day produce less than the average, and thousands of them fail to produce enough to pay market value for the feed they consume. Furthermore these inferior cows continue to add their yearly quota of unprofitable offspring to the herds of the country. The dairy farmer has no way of knowing for certain whether a heifer born in his herd will be a profitable producer or not, until she has been milked for at least a year. By that time she will be close to 3 years old and will have cost him from $100 to $150 for her keep. It is estimated that more than one third of the 5 or 6 million heifers raised for replacements each year turn out to be unprofitable producers.

To eliminate the enormous loss caused by raising heifers that are predestined to be unprofitable producers, as well as to raise the per-cow producing efficiency of our herds, it is essential that we develop a scientific breeding plan which will assure the dairy farmer of consistent and uniform results from his matings. The many different ideas, theories and practises with regard to breeding high-producing animals have not accomplished uniformly good results. True, many high-producing individual animals have been developed here and there, and even whole herds have been brought to a high average level of production. But few if any individual breeders have been financially able or scientifically inclined to carry on breed-

ing experiments under "controlled conditions" or for a sufficient length of time to accurately determine the merits of their particular theories and practises. A practical breeding program involves more than a system of mating outstanding individuals. It involves a knowledge of many fundamental facts about heredity, health, nutrition and countless other phases relating to reproduction. And since such a program is obviously a national necessity its development has become a task for the government research worker.

The Bureau of Dairy Industry started the task of developing a scientific and practical breeding program in 1918 by making an extended study of existing theories and practises. Dairy breeders, like breeders of other live-stock, had for many years been divided into three schools of thought regarding the best system of mating to obtain desired results. One school advocated linebreeding, another close inbreeding, and the third would mate only unrelated animals. Along with these practises went a number of other ideas of breeding, the result being that farmers and breeders were working in a maze of theory without any scientific basis for guidance. Since no actual experimental work had ever been carried on under controlled conditions to determine whether one system was more likely to produce desired results than another, experimental breeding herds were established at the Beltsville farm and at various other field experiment stations to test the respective merits of inbreeding, linebreeding and outcrossing. Projects were planned to continue indefinitely, or until the results could be considered conclusive.

Students of genetics had by that time come to some rather definite conclusions about the laws of heredity. They saw little possibility of applying these laws to the breeding of dairy cattle, however. It remained for the bureau scientists to point out the application of the new knowledge of heredity in the selection of dairy sires. As a result of statistical studies, involving many production records of registered dairy cattle, they concluded that the most successful sire is one that is "pure," or homozygous, in his general make-up for factors that govern the transmission of high milk and butterfat production. The better understanding of heredity indicated that the best way to measure a sire's germinal make-up, or transmitting ability, is through a study of the production records of a large number of his daughters. The bureau scientists then reasoned that if a sire has demonstrated his ability to beget daughters all or most of which are better producers than their dams, this may be taken to indicate that he has a high degree of homozygosity, or "purity" in his germinal make-up, for the factors that determine high production. They reasoned further that the use of such homozygous sires in a herd, for generation after generation, would gradually build up the inheritance in the herd until it is fixed for a high level of milk production, a high butterfat test, or both, depending on the basis of selecting the sires.

Out of this new knowledge has come the so-called "proved sire" system of breeding, in which attention is centered on the use of sires that have proved their ability to sire daughters that are better producers than their dams.

For nearly 15 years now we have been selecting sires on this basis for the breeding herds at our various field stations, and we have made remarkable progress in developing strains or herds that are approaching purity in their inheritance for high production. Also during this time our experiments with inbred and outbred animals have indicated a most important principle, namely, that when a sire has proved, through the production performance of his daughters, that

he is homozygous for the factors that determine high production, he will transmit the inheritance for high production to all his offspring regardless of whether he is related or unrelated to the females with which he is mated. It also appears that such unrelated sires, within a breed, have the same factorial make-up for milk production. This is important, indicating that selection of sires need not be confined to the same family.

In our experimental herds we are using proved sires, generation after generation, without regard to their relationship to each other. At one station we are using Holstein sires that have proved that they possess an inheritance for a high butterfat test. We already have records on the daughters of the third proved sire used in this herd and these daughters have butterfat tests ranging between 3.7 and 4.0 per cent. It appears that we are well on the way toward fixing an inheritance for a 4 per cent. level in this herd.

As a result of our progress in developing pure-line-production herds and in spreading genetic knowledge, farmers and breeders are taking a keen interest in the use of proved sires to head their herds. At present, however, the number of bulls that prove to be genetically pure is very limited, but we have demonstrated that the sons of proved bulls can be used with greater assurance that they will transmit high production than untried bulls. As a part of our breeding studies at the various field stations, all young sons of proved sires are placed in farmers' herds in the vicinity of the station for the purpose of proving their transmitting ability. The 505 daughters of 52 young Holstein bulls loaned to farmers near the Huntley, Montana, station have production records that exceed their dams' records by an average of 1,601 pounds of milk and 69.15 pounds of butterfat. Of these 505 daughters, 384 exceeded their dams in milk production and 412 in butterfat production. The 76 daughters of 12 young Jersey bulls loaned from the Beltsville herd have records that exceed their dams' records by an average of 716.5 pounds of milk and 57.4 pounds of butterfat. Of these 76 daughters, 48 exceeded their dams in milk production and 58 in butterfat production.

Because great sires are few and far between, much of our research work is directed toward prolonging the active life of all known proved sires, or toward perpetuating their "superior germ plasm" in other ways. For that reason we are studying the factors involved in artificial insemination and in the preservation of bull spermatozoa. If sperm cells could be kept alive for a period of several days, semen from a great breeding sire could be used on females coming in heat later on, or it might be transported over long distances and used to inseminate a number of animals. To date we have been able to maintain the viability of sperm cells for 82 hours under laboratory conditions. Other research work has shown the importance of enforced exercise and of certain feeds, particularly sprouted oats, in maintaining fertility in aged sires. The average sire will not breed beyond the age of 10 years, but we have been able to keep a few fertile to the age of 16 years.

While we are attempting through breeding research to develop an efficient "milk producing machine" we are not losing sight of the fact that the economical performance of the machine depends to a great extent on the "fuel" or feed we supply. For many years the farmer merely gave a milk cow what feed he had handy, and let her do the best she could with it. Now we know, as a result of our research, that the kind and quantity of feed affect her efficiency, or profitableness, in three ways. Feed affects (1) the quantity of milk produced, (2) the nutritive properties of the milk, and

(3) the health and reproductive functions of the cow.

Roughages, which are the natural and cheapest feeds for dairy cows, until very recently had not received the attention from research workers that their importance warranted. Our studies in nutrition have uncovered some immensely interesting facts about the value of different kinds and qualities of roughage. It was long known that alfalfa hay contains much more protein and calcium than timothy hay, but we have found that alfalfa hay also contains other properties of nutritive superiority, particularly vitamin A. Furthermore, we have found that these properties vary not only with the kind of hay, but with the different grades or qualities of a hay. Feeding experiments indicate that the vitamin A content of No. 1 alfalfa hay is 4 times as high as that of No. 3 alfalfa hay, 10 times as high as that of No. 1 timothy, and 30 times as high as that of No. 3 timothy. Cows fed the year round on grain and No. 1 alfalfa hay will produce satisfactorily and yield large quantities of milk for periods of from 5 to 10 years at least, whereas cows that are fed on grain and No. 3 timothy hay will not only begin to throw premature calves and dead calves within 6 months but will usually die or become useless as dairy animals within 3 years.

Other research workers had shown that there is a close relationship between vitamin A and carotin, which is one of the yellow pigments of grasses and other forage crops. It is now known that this vitamin is formed in the body of the animal from carotin in the feed, and transferred to the milk. The carotin content of the feed therefore becomes of great importance in feeding dairy cows, not only to maintain their health and reproductive functions but to keep the vitamin A content of the milk high for human nutrition.

We now have evidence that the greener the hay the higher its carotin content, so we have recently started some experiments to determine the best methods of curing and storing hay in order to preserve its natural green color. So far we have found that hay stored in the absence of light and air and at a temperature near freezing for 8 months will lose no color. Artificially dried hay that had a low moisture content lost but little color when stored in the absence of light and air and at room temperature; and there was no excessive loss of color when it was exposed for 8 months to either diffused sunlight or air, or both. The naturally cured hays had less color and more moisture than the artificially dried hays and when stored in the absence of air at room temperature sustained a marked loss of color. Apparently, quick and thorough drying is the main factor in making hay that will have and retain a high color.

These investigations have not only shown the importance of improving the quality of roughage from the standpoint of the effect on the nutritive properties of the milk, but they indicate that the growing and feeding of good roughage to good cows affords the dairy farmer his greatest opportunity to reduce feed costs. Actual feeding experiments prove that roughage is more nutritious and more palatable when cut in the earlier stages of maturity than when allowed to ripen before cutting, and that the immature cuttings yield more protein per acre. We have also shown that immature grasses, in the form of green pasture, hay, or silage, are far superior to mature grasses in maintaining milk yield. Furthermore, crop production surveys have shown that the nutrients required for milk production are generally produced cheaper in the form of roughage than in the form of grain. In a feeding experiment at one of our field stations cows that were fed nothing but

DAIRY CATTLE BREEDING SCHOOLS POPULAR

BUREAU SCIENTISTS DEVISED THE HERDISCOPE TO EXPLAIN THE LAWS OF INHERITANCE AND THEIR APPLICATION IN DAIRY CATTLE BREEDING.

good alfalfa hay produced 75 per cent. as much butterfat as when they were fed heavily on grain, with roughage, and at approximately half the cost. This information suggests that dairy farming, in many instances, would be more profitable if the farmer would devote all or most of his land to pasture and forage crops, and feed grain only when the price of milk and the additional yield would warrant the purchase of grain.

A profitable dairy industry depends on other factors than efficient and economical production on the farm, however. The quality of milk and of its various manufactured products plays an important rôle, not only because the better quality products usually sell at a premium but because satisfactory quality exerts a favorable influence on total consumption of dairy products.

To be of the highest quality, milk must be clean and sweet, pleasing in flavor, and free from abnormal odors and undesirable bacteria. The first essential is that it be safe for consumption, that is, free from disease-producing bacteria The tendency to-day is to pasteurize practically all milk sold for direct consumption. But this practise did not become established without considerable opposition at first. Pasteurization was first recommended for milk by a noted American health authority in 1889, nearly 30 years after Louis Pasteur, of France, had found that heating would prevent souring and abnormal fermentation in wine and beer. At first the heating of milk was done secretively and for the sole purpose of preserving the milk to save losses to dealers. The early objections were gradually overcome as many scientists studied the subject and provided fundamental knowledge on the bacteriology and chemistry of milk. In this work the Bureau scientists played an important part by demonstrating that, from the bacteriological standpoint, proper pasteurization leaves the milk in the condition of fresh milk pro-

DAIRY FARMERS STUDYING RESEARCH RESULTS

DELEGATIONS OF DAIRYMEN ARE A COMMON OCCURRENCE AT THE BELTSVILLE EXPERIMENT FARM, TESTIFYING TO THEIR INTEREST IN THE RESULTS OF DAIRY RESEARCH.

duced under sanitary conditions but with the danger from pathogenic bacteria eliminated They also showed that approved methods of pasteurization produced no objectionable chemical changes in the milk. The process is to-day accepted by health authorities, scientists, and dairy interests as the best means of killing pathogenic bacteria in milk on a commercial scale.

Millions of gallons of milk are rejected from the fluid milk market every year because of undesirable feed flavors and odors. If such milk were accepted it would have a very detrimental effect on consumption, for it is a fact that the quantity of milk consumed is dependent primarily on its palatability. In the course of studies started 20 years ago to determine how to avoid these undesirable flavors and odors we found that the flavors and odors from feeds and weeds eaten by the cows pass through the body of the cow to the milk in the udder, instead of being absorbed directly from the air as was formerly believed. We found also that some feeds and weeds continue to impart their characteristic flavor to the milk for a much longer time than others, after the cow has eaten them. For instance, garlic, which is one of the most troublesome weeds in this respect, flavors the milk within a few minutes after the cow has eaten it, and the flavor does not entirely disappear for about 7 hours. In fact, garlic will flavor the milk when the cow merely inhales its odor. Other feeds, we learned, impart their flavors to milk for only an hour or two, so out of this knowledge we have evolved practical feeding practises by which dairymen can get the benefits of certain highly-flavored feeds, such as silage, turnips, cabbage, kale, sugar beets and the like, and yet produce milk that is normal in flavor and odor. Since most feeds impart their flavors to milk for only a few hours after feeding, it is possible to avoid their flavors by feeding immediately after milking and not before. That gives the flavors time to disappear from the body of the cow before the next milking. If the principles laid down by our research workers were followed more generally by dairymen it would add from 15 to 20 million dollars

annually to the value of milk sold from farms.

Thirty years ago when we began our butter investigations the creamery industry was comparatively new. Less than one third of all butter made in this country was made in creameries, the rest being made on the farms. The result was a great variation in the methods of making and in the quality of the product. Nearly all butter held in storage developed fishy, oily or metallic flavors causing serious loss in value. Our early investigations showed that many of the deteriorations in butter were chemical in nature and that the acidity developed in the cream was an important factor in accelerating changes in the butter. The earlier practise, developed before pasteurization was generally adopted in the butter industry, was based on the assumption that a high acidity was necessary to inhibit bacterial action in the butter. Since the detrimental effect of acidity was shown nearly all factory butter is made from cream with a low acidity and the troubles from fishy, oily and metallic flavors have nearly disappeared. A large quantity of butter is now made from pasteurized cream without any ripening whatever. This is the so-called sweet-cream butter, which was first recommended by this Bureau for the navy, and which, on account of its superior keeping qualities, is especially adapted for shipment and storage. Such butter is known as sweet-cream butter, and is made from cream of low acidity in which the acid has been properly standardized. The improved quality of creamery butter, together with many other scientific developments in factory butter making, has been largely influential for the change in butter making from the farm to a factory basis. Today more than three fourths of all our butter is factory made.

Research by the Bureau's scientists has also played an important part in the great improvement in quality of ice cream in the last decade. In the beginning of the commercial ice cream industry the product contained a low proportion of those valuable materials in milk that are known as milk solids, and it was rarely ever made from pasteurized milk

EXERCISING BULLS AT BELTSVILLE

ENFORCED EXERCISE HELPS TO PROLONG THE ACTIVE LIFE OF OUTSTANDING DAIRY SIRES.

A DAIRY RESEARCH LABORATORY
FUNDAMENTAL RESEARCH, IN ADDITION TO PRODUCING RESULTS OF IMMEDIATE PRACTICAL VALUE, OFTEN PRODUCES INFORMATION WHICH LEADS TO UNEXPECTED DEVELOPMENTS.

and cream. Early in its studies of consumer preferences the Bureau found that most persons preferred ice cream rich in butterfat, sugar and milk solids not fat However, when manufacturers attempted to increase the percentage of milk solids they had difficulty in making a product that was free from grittiness, or "sand" as the characteristic was termed. Research work on this problem indicated that "sandiness" was due to an excess concentration of milk sugar, which formed crystals when the ice cream was subjected to varying temperatures in the hardening rooms or in the dealers' cabinets. Methods have been developed by which a large percentage of the milk sugar in condensed skim milk can be removed. The resulting condensed skim milk, low in milk sugar content, can be used to increase the milk solids content of ice cream from the normal 10 per cent. to 12 per cent., without the danger of sandiness. If as a result of this work the average milk solids not fat content in ice cream should be raised by only 1 per cent. it would provide an additional market for 1,540,000,000 pounds of skim milk annually.

The manufacture of nearly all milk products is dependent on the control of the growth of bacteria. This control can not be exercised properly without a knowledge of the conditions which govern the growth, the activities and the death-rate of the bacteria. After many years of study and research in connection with these basic problems the Bureau scientists have recently perfected methods of making Swiss cheese of a quality equal to the imported product. Their investigations established the fact that the quality of Swiss cheese is dependent largely on the growth, at the proper rate and in definite sequence, of at least 3 species of bacteria. To help Swiss-cheese makers produce a high-grade product the Bureau now supplies cultures of these bacteria for making the right kind of starters. About 25,000,000 pounds of Swiss cheese is now made annually in this country and each year an increasing percentage is being made by the culture methods; and since the culture cheese ordinarily sells for 2 cents a pound more than non-culture cheese this research has a potential value of at least $500,000 a year to the dairy industry.

Such fundamental research, in addition to the results of immediate practical value, often produces information which leads to unexpected developments. In connection with these early studies on gas-forming bacteria in cheese, one of the Bureau scientists became interested in the effect of acid on the growth of bacteria. At that time it was customary to measure the acid in bacteria preparations by titration, although it was then known that titration measured the quantity rather than the intensity of the acid present. Physical chemists were aware that the intensity of the acid as determined by the dissociation of the acid,

and measured by determining the hydrogen-ion concentration, was of greater significance than the value determined by titration. The Bureau scientist pointed out the fact that the checking of bacterial growth in any kind of medium was due to the hydrogen-ion concentration, or acid intensity, and not to the titratable acidity; thus a few tenths of one per cent of hydrochloric acid, which is strongly dissociated, would have the same effect on bacteria as 20 per cent of a weaker acid like citric, which is only slightly dissociated He developed accurate methods for measuring hydrogen-ion concentration and published a book on the subject which became the standard work throughout the world. He also synthesized a series of indicators by which hydrogen-ion determinations could be made quickly and accurately.

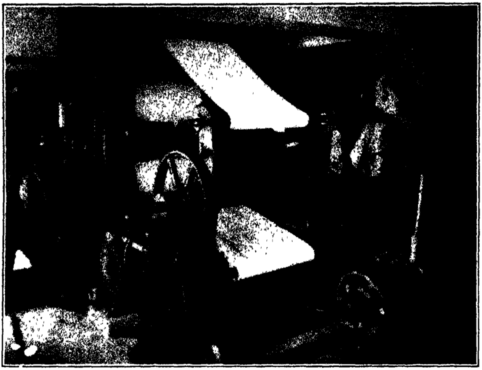
While this new understanding of the relation of hydrogen-ion concentration to the control of bacterial growth was the result of a Bureau worker's absorbing interest in "pure science" it has had a very far reaching effect in many industries. To-day the laundry industry controls the reaction of its wash waters and rinse waters by means of the indicators developed in the Bureau's laboratories.

This information also had an immediate effect on our other investigations of a practical nature. When the United States went into the world war there was a demand for a large amount of casein with a high degree of purity for use in making waterproof glue for airplane construction. The problem was referred to this Bureau and it was immediately determined that casein with a high degree of purity could be made by bringing the skim milk to a certain hydrogen-ion concentration, at which point the casein would be precipitated in small firm flecks, which would permit a thorough washing to remove impurities. The method proved to be satisfactory. Methods now in use in making commercial casein are based on the fundamental information developed at that time.

Along about this time we were also working on the molds involved in the ripening of Roquefort cheese. In studying the acid formation by these molds we found one that was exceptionally active in producing citric acid by the fermentation of sugars. By applying our knowledge of hydrogen-ion concentration we were able to control the growth of the mold by controlling the reaction of the medium on which it was grown, thus providing conditions favorable to the growth of this particular mold but unfavorable to the growth of contaminating bacteria. This was the first time that molds were used in commercial fermentation. A chemical company is now manufacturing a large quantity of citric acid by the use of this method, which displaces the citric acid formerly pro-

MAKING SWISS CHEESE

AMERICAN CHEESEMAKERS CAN NOW MAKE SWISS CHEESE OF AS GOOD QUALITY AS THE IMPORTED CHEESE BY FOLLOWING APPROVED METHODS OF BACTERIOLOGICAL CONTROL.



CASEIN USED FOR PAPER COATING

DAIRY SCIENTISTS, IN COOPERATION WITH THE BUREAU OF STANDARDS, HAVE DEVELOPED IMPROVED METHODS FOR MAKING PAPER-COATING CASEIN. THIS MACHINE IS IMPARTING THE SPECIAL FINISH REQUIRED FOR HALF TONES.

duced from citrus fruits and imported from Italy and Greece.

The third major field of research through which the Bureau seeks to enhance the profitableness of the dairy industry is concerned with the development of new ways to utilize dairy by-products. More than 3,500,000,000 pounds of milk solids are contained in the skim milk, buttermilk, and whey produced as by-products in the manufacture of butter and cheese each year. These by-products are often wasted or utilized so inefficiently that the returns to the producer are small.

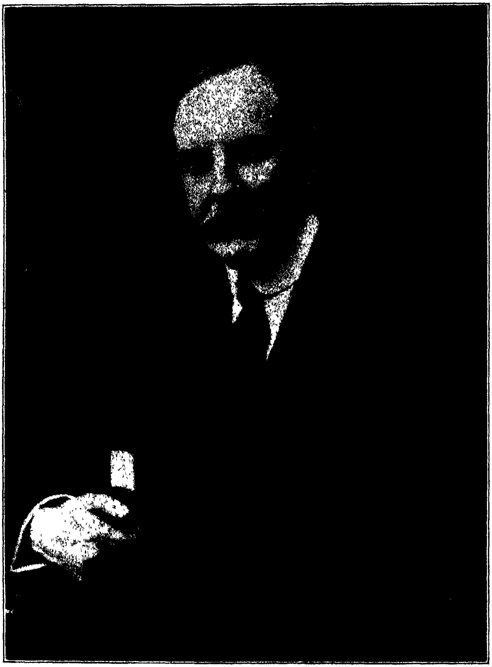
Considerable progress has already been made as a result of our research in the chemical and bacteriological phases of milk. Several years ago we discovered that certain difficulties in condensing skim milk to a point at which the acidity would be sufficient to make the product self-preserving could be overcome by using special high acid producing cultures. About 75 million pounds of skim milk are now converted into concentrated sour skim milk annually, a form in which it may be held indefinitely or transported long distances for feeding to poultry and hogs in sections where there is a shortage of dairy products.

We have also found that modifications in the methods of manufacturing skim milk powder will greatly increase its desirable effects when incorporated in bread and ice cream, and it is estimated that if all the bread were made with the most desirable quantity of skim milk

powder there would be a satisfactory market for all the skim milk produced in butter making.

The Bureau has long considered the possibilities of marketing much of our skim milk in the form of casein. Casein is used for many purposes, but more than 75 per cent. of all casein sold in this country is used by the paper-coating industry. Until the last few years more than half the casein used in the United States was imported, chiefly because our domestic product was inferior in quality Domestic casein is now of higher quality and greater uniformity largely because of the information developed and introduced into commercial practise by the Bureau.

In the manufacture of cheese and casein, vast quantities of whey are produced and every 100 pounds of this whey contains from 4 to 5 pounds of milk sugar. The value of milk sugar as a constituent of baby foods and in the diet of patients suffering from intestinal disorders has long been known to medical science. Considerable quantities are also used in making medicinal tablets. The 12 million pounds manufactured annually is far less than could be produced if there were a greater demand for it and that is why we are endeavoring to develop new uses for this valuable milk solid. Milk sugar is not nearly so sweet as cane sugar, and this fact undoubtedly is responsible for its restricted use in the diet. A few years ago, however, one of our scientists perfected a method by which milk sugar can be recovered in a form that has a higher degree of sweetness and greater initial solubility than the usual commercial form There is every reason to believe that the newer form has the same physiological effects as the older form and that it may in time supersede it as the milk sugar of commerce. There are many uses for milk sugar in the industries, as for instance in confectionery and in explosives, providing the sugar can be produced at a sufficiently low cost. The Bureau has developed methods by which a satisfactory grade of sugar can be produced at a cost materially lower than that of the ordinary pharmaceutical grade



PROFESSOR ARTHUR E. KENNELLY

THE PROGRESS OF SCIENCE

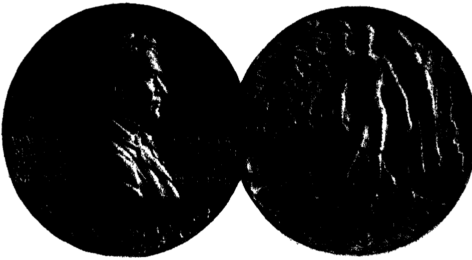
THE PRESENTATION OF THE EDISON MEDAL TO PROFESSOR KENNELLY

THE Edison Medal of the American Institute of Electrical Engineers, which was awarded to Professor Arthur E. Kennelly in December, 1933, was conferred on him personally with appropriate ceremonies at the United Engineering Societies Building in New York on the evening of January 24. This medal was established by friends of Mr Edison who had been associated with his developments of the incandescent electric lamp and systems for the distribution of electricity. Its purpose is to do honor to Mr. Edison's name and to celebrate further "Achievement in Electricity." It is one of the notably distinguished medals which are conferred solely in the engineering field and for distinguished achievement therein The first Edison Medal was awarded in 1909 to Professor Elihu Thomson, who was followed as recipient in successive years by Sprague, George Westinghouse, William Stanley, Brush, Bell, Tesla, Carty, Lamme, Emmet and like distinguished contributors to our understanding of electrical phenomena and to the utilization of electrical power. Twenty-three of these medals have been conferred in a quarter of a century, there having been two omissions of annual awards.

The latest recipient, Dr. Kennelly, now emeritus professor both in Harvard University and in the Massachusetts Institute of Technology, was born in Bombay, India, in 1861, of British parents. His early education was in schools in England and Scotland. At the age of fifteen he became a telegraph operator in England and two years later took up work as assistant electrician of a cable station and thereafter became chief electrician in cable-laying work, which character of work has continued with him as a memory of heart's love. It was during these years that reflection and reading laid the foundation for his notable contributions to electrical engineering Coming to this country in 1887, Professor Kennelly thereupon became identified with electrical engineering in America primarily, but his expanding reputation during the ensuing years has become international.

Professor Kennelly has been a profuse author in the field of electricity. Some of his writings have exerted a specific influence on the teaching of electrical engineering in certain aspects of electric circuit analysis, and these productions are well acclaimed by competent students in our engineering colleges and in the electrical industries. He has also been much sought after as a lecturer, here and abroad, as is witnessed by his professorships and his selection in the winter of 1921–22 as an exchange professor with France and in the autumn of 1931 as Iwadare lecturer in Japan. He is a member of many learned societies and has heretofore received many American and foreign honors The memorable significance of his contributions to electrical engineering is well proved by his honors from his colleagues in that branch of learning. He was elected president of the American Institute of Electrical Engineers in 1898 and was reelected in 1899, in which post a second term is almost unique. He now is an honorary member of that society as well as the corresponding society of Great Britain and of France.

The Edison Medal was conferred on Professor Kennelly with the following citation: "For meritorious achievements in electrical science, electrical engineering, and the electrical arts as exemplified by his contributions to the theory of electrical transmission and to the development of international electrical standards." His authoritative writings in



THE EDISON MEDAL

electrical engineering have ranged over a wide area, comprising submarine cables, electrical communication apparatus, electrical machinery, electric circuits and radio communications. His endeavors have been exerted also in many fields aside from electrical engineering. These are exemplified, for example, by his strong advocacy of the adoption in this country of the metric system of weights and measures for manufacuring and commercial purposes. His international influence is well illustrated by his association for many years with the International Electrotechnical Commission, and by his now occupying the post of president of the International Scientific Radio Union as the successor of the greatly esteemed General Ferrié of France.

Electrical engineering in America is peculiarly indebted to Professor Kennelly, among other things, for his ardent support of the merits of hyperbolic trigonometry in electrical engineering computations and his continued industry from 1905 to 1915 in computing and publishing tables and charts of hyperbolic functions so as to fill the gap which then existed in such working data. Associated with this work were many illuminating geometric interpretations of the mathematical equations and equally illuminating discussions of mechanical analogies of electrical impedances.

D. C. J.

THE ADMINISTRATION OF THE WEATHER BUREAU

Willis Ray Gregg, former chief of the aerological division of the U. S. Weather Bureau, has been appointed by President Franklin D. Roosevelt to the position of chief of the Weather Bureau. Mr Gregg brings to these greatly broadened responsibilities an ample educational foundation, obtained at Cornell University, where he received his bachelor of arts degree in 1903. To this he has added 29 years of intensive training and experience in actual Weather Bureau work. Beginning at the bottom as an assistant observer at Grand Rapids, Michigan, in 1904, he has risen to the top of his profession.

Having specialized in upper-air research during the last 16 years, he has at all times been in the front rank in serving the rapidly developing aviation industry. He is the author of an excellent text-book, "Aeronautical Meteorol-

ogy," which is simple enough for the amateur and the pilot, yet advanced enough to satisfy the technical student. He is a member of the National Advisory Committee for Aeronautics, the A. A. A. S. and numerous other scientific and philosophical societies. He has prepared many valuable papers of technical character. With his ripe experience, Mr Gregg combines physical vigor, keenness of mind and a pleasing and forceful personality, that should serve him well in his new duties, which will be more largely administrative than scientific

Dr. Charles F Marvin, retiring from the chiefship of the bureau at the age of 75, impresses one as too valuable to be retired. Both Presidents Hoover and Roosevelt shared this opinion and continued Dr. Marvin more than five years beyond the usual retirement age. He will be retained as an associate of Mr. Gregg to assist him in grasping the reins of this complex bureau until Dr. Marvin soon rounds out an even half century of Weather Bureau service. An adequate account of Dr. Marvin's valuable service to the people of the United States in these 50 years would require a book. His first college degree was attained in mechanical engineering at Ohio University in 1883. Most of the instruments now used by the Weather Bureau were devised or perfected by Dr. Marvin. His thorough training in mathematics and physics has ever kept him in conservative lines, not easily disturbed by superficial theorists and quacks who are always getting the newspaper headlines with untenable methods of weather forecasting and condemning the Weather Bureau because it does not adopt their "new" methods.

Dr Marvin has endeared himself to all his staff of workers, in and outside of Washington, by his humanitarian treatment and his patient hearing of proposals, suggestions and complaints. The many heartbreaking orders that had to be issued to faithful subordinates during the last two years are generally regarded by the men affected as part of the exigencies through which the country is passing and not the fault of their revered chief.

A committee of the Science Advisory Board, set up by President Roosevelt in 1933, was assigned to Weather Bureau problems. Its report, recently handed up through the Secretary of Agriculture to the President, noted that Weather Bureau service probably touches the daily lives of more people

CENTRAL OFFICE OF THE U. S. WEATHER BUREAU AT WASHINGTON, D. C.

DR. C. F. MARVIN
RETIRING CHIEF OF THE UNITED STATES WEATHER BUREAU

than all other federal services combined, with the single exception of the postal service

The Weather Bureau has always been cognizant of the three-dimensional nature of its atmospheric problems and, by the use of kites, balloons and finally airplanes, has sought to bring together upper-air data of sufficient quantity and promptness. Airplane observations have proved most dependable, but it costs about $10,000 a year to maintain one flight of required altitude daily at a single station. Weather Bureau appropriations provide for only four airplane stations. The committee arranged tentatively for cooperation with the Army, Navy and technical schools so that the number of such stations will be increased to about 25 as a beginning, and it is hoped that others may be added.

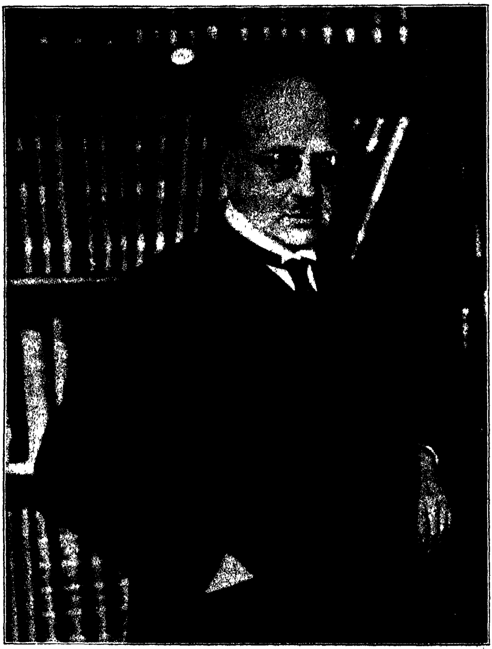
With these improved facilities it will be possible to reach the dignity of "Air Mass Analysis," a new term coined to celebrate the acquisition of better data and the achievement of better methods of forecasting. Gradually, the new method will be introduced as the data become available and personnel can be trained. There is also the possibility of

WILLIS R. GREGG
NEW CHIEF OF THE UNITED STATES WEATHER BUREAU

monthly or seasonal forecasts when the climatology of higher levels has been established up into the stratosphere with something of the same completeness as that at the surface of the earth.

With a decrease in appropriations of $1,587,836, or 35 per cent., in the last two years, in the face of continually increasing demands for service, the new chief is confronted with extraordinary administrative problems. Aviation is particularly helpless without adequate Weather Bureau assistance, yet aviation can not be fully served with the funds available without drawing from the services to agriculture, engineering, commerce and general transportation, though all, particularly the engineers, are clamoring for more service. Many important stations are undermanned and the standards of salary and training have been lowered at a good many vital places. The personnel have borne the larger part of the curtailment, so far, but if some great weather catastrophe should occur, the public might pay large toll. It can be shown that Weather Bureau service to agriculture has saved as much as $100 for every dollar the service cost.

CHARLES D. REED



FRITZ HABER

DISTINGUISHED GERMAN CHEMIST, WHO DIED IN SWITZERLAND ON FEBRUARY 1. UNTIL LAST YEAR PROFESSOR HABER WAS DIRECTOR OF THE KAISER WILHELM INSTITUTE FOR PHYSICAL CHEMISTRY AND ELECTROCHEMISTRY. IN 1919 HE WAS AWARDED THE NOBEL PRIZE IN CHEMISTRY FOR DISCOVERING THE "HABER-BOSCH" PROCESS FOR THE FIXATION OF ATMOSPHERIC NITROGEN.

MAN—PAST AND PRESENT—IN THE FIELD MUSEUM

DURING the summer of 1933, the Field Museum of Natural History, Chicago, opened two new large exhibition halls in the Department of Anthropology. The Hall of the Stone Age of the Old World presents the story of man's evolution and development during prehistoric ages, by means of eight life-size diorama groups and fifteen cases of archeological material. In the Hall of Races of Mankind, 100 life-size bronze sculptures (full-length figures, heads and busts) portray typical members of the great racial divisions of the human family living to-day.

In the Hall of the Stone Age of the Old World the first of the groups presents a moonlight scene in northern France during Chellean times, 250,000 years ago. Beside a meandering river two hunters have built a fire, while on the opposite bank the great animals of the time are watching the flickering light. The dim and shadowy scene suggests the incompleteness of our knowledge of that early period.

Group II shows a Neanderthal family at the entrance to Devil's Tower rockshelter at Gibraltar. Group III portrays the dawn of art, magic and religion. Here an Aurignacian artist is kneeling before the frieze of mutilated hands in the cave of Gargas in southern France. Group IV shows a Solutrean sculptor of mongoloid type carving a horse on a block of limestone in front of the frieze of pregnant animals at Le Roc, Charente. In a smaller case is a reproduction of the Tuc d'Audoubert bisons of clay; and opposite is the original Cap-Blanc skeleton of a young Magdalenian girl. Group V is a natural size reproduction of the Cap-Blanc rockshelter in the Dordogne district of France. Group VI portrays an Azilian boar hunt at the entrance to Mas d'Azil, Ariège, emphasizing the first domestication of the dog. Group VII shows the great Alignment at Carnac in Brittany, where a priest of the Neolithic age, with arms upraised, worships the sun as he welcomes the birth of a new day. The final diorama of the series is an early morning scene at Lake Neuchâtel, Switzerland. Two fishermen are dragging a large seine to shore, and a typical Swiss lake-dweller village is painted in the background.

The life-size human figures and the installation of each group are the incomparable work of Frederick Blaschke, who obtained assistance from Sir Arthur Keith, Professor G. Elliot Smith and the Abbé Henri Breuil. His results are therefore as accurate as present knowl-

FIELD MUSEUM OF NATURAL HISTORY, CHICAGO

CHELLEAN MOONLIGHT SCENE IN NORTHERN FRANCE, 250,000 YEARS AGO[1]

edge warrants Charles A. Corwin, staff artist of Field Museum, is responsible for the remarkable painted backgrounds.

The archeological material includes the type collection from Solutré and many other important treasures, all of which were acquired by me with the co-operation of the Abbé Breuil, who assisted me in planning the hall. There are also tens of thousands of archeological objects available to students in the study collections of the Department of Anthropology. The work on this hall, begun early in 1927, was completed in August, 1933.

The Hall of Races of Mankind was planned to show the main divisions of the human race assembled together in one great exhibition hall for the purpose of study and comparison. Breaking away from the traditional museum schemes for presenting physical anthropology exhibits, a great sculptor, Malvina Hoffman, was employed for this important task. The eminent English scientist, Sir Arthur Keith, was keenly interested in the project, and gave Miss Hoffman much valuable advice in her work. She traveled around the world in

[1] The illustrations in this article are reproduced through the courtesy of the Field Museum of Natural History

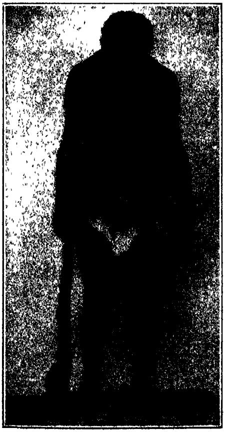
CHAUNCEY KEEP MEMORIAL HALL

WITH BRONZE FIGURES OF RACIAL TYPES OF MANKIND, BY MALVINA HOFFMAN, SCULPTOR.

search of models, and everywhere received assistance from qualified anthropologists.

The hall is arranged in the following manner: The center is dominated by a symbolic group of heroic size, the Unity of Mankind, representing the three main branches of the human race—a black, a white and a yellow man. Around the walls, set in alcoves, are the main variations within these three groups, geographically arranged by continents. In the African section the family groups of Kalahari Bushmen and Ituri Pygmies are valuable from an esthetic as well as an anthropological point of view. There is also a tall young Shilluk warrior, resting on one leg in the curious stork-like pose characteristic of his people. In striking contrast to his serious mien, is the beautiful Sara girl poised in the graceful attitude of a rhythmic dance.

In the European section there are full-length figures of Nordic and Mediterranean types. The representatives of Asia include a Veddah, Kashmiri, Tamil, Andamanese, Tibetan, Chinese jinriksha coolie and an aged Ainu. From the Pacific area, a Hawaiian surf-rider, a Solomon Islander, Semang pygmy with blow-gun, an Australian family group and a Malayan cock-fighting group are shown. It is impossible here to describe the numerous other types represented in this hall.



NEANDERTHAL MAN
RESTORED BY FREDERICK BLASCHKE, SCULPTOR.

A BLACKFOOT INDIAN
BY MALVINA HOFFMAN, SCULPTOR.

In her sculptures Malvina Hoffman combines realism with artistic power. In the words of Sir Arthur Keith, "Malvina Hoffman is a great sculptor who lavishes her art in the service of anthropology." Students and visitors owe a debt of gratitude for her great contribution to art and science.

A small section at the east end of the hall will be devoted to exhibits dealing with the more technical aspects of physical anthropology These will include variations in stature, color of eyes, skin, hair, etc. The effects of epidemics and disease on populations, as well as demography, will be illustrated.

These two halls were planned and directed by me in cooperation with Dr. Berthold Laufer, curator of the Department of Anthropology.

HENRY FIELD,
Assistant Curator of Physical Anthropology
FIELD MUSEUM OF NATURAL HISTORY

HIGH ALTITUDE WEATHER OBSERVATIONS

PLANS for a study of weather conditions in the stratosphere by means of sounding balloons carrying delicate recording instruments, with supplementary high altitude observations by airplane, were recently announced at the Massachusetts Institute of Technology. Professor Carl G. Rossby, director of the meteorological laboratory, will direct the new stratosphere studies from the Lambert Field Airport at St. Louis.

Forty balloons, which are about four feet in diameter when inflated, will be released from this observation post. They will carry specially designed instruments weighing only a few ounces each, which will automatically make records of temperature, humidity and atmospheric pressure. The balloons will rise many miles above the earth and will burst in the rarefied air of the stratosphere. The instruments will be enclosed in bamboo shock-absorbing frames, and the fluttering fragments of the broken balloon are being relied upon to break their speed of descent.

Many of the balloons are expected to reach an altitude of twelve miles above the earth. They may be carried great distances by wind currents, and each balloon will bear an identification tag offering a reward of $5 00 to the finder, provided the instruments and their records are not tampered with. Further instructions will advise finders how to care for the instruments until Professor Rossby sends a special shock-absorbing container in which to ship them to his laboratory.

A mid-continental location for the experiment was chosen in the hope that most of the instruments would be found on land. To carry out the study in New England, where the prevailing winds are from the west, probably would result in the loss of most of the balloons at sea. These upper-air observations are expected to contribute to the knowledge of meteorological conditions in the atmosphere and to advance studies of weather forecasting. This research program has been made possible by a grant of over $8,000 from the Rockefeller Foundation.

THE SCIENTIFIC MONTHLY

APRIL, 1934

'HE CONTRIBUTIONS OF SCIENCE TO INCREASED EMPLOYMENT[1]

A LETTER FROM PRESIDENT ROOSEVELT[2]

The value to civilization of scientific thought and research cannot be questioned. To realize its true worth one has only to recall that human health, industry and culture have reached, in a century of scientific progress, a far higher state than ever before.

The idea that science is responsible for the economic ills which the world has recently experienced can be questioned. It would be more accurate to say that the fruits of current scientific thought and development, properly directed, can help revive industry and the markets for raw materials.

SCIENCE MAKES JOBS

By Dr. KARL T. COMPTON

PRESIDENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY; CHAIRMAN SCIENCE ADVISORY BOARD; CHAIRMAN, AMERICAN INSTITUTE OF PHYSICS

THE idea that science takes away jobs, or in general is at the root of our economic and social ills, is contrary to fact, is based on ignorance or misconception, is vicious in its possible social consequences, and yet has taken an insidious hold on the minds of many people. Conscious of the fallacy of this idea, but characteristically intent on their work and averse to publicity, the productive scientists of the country have thus far taken little or no part in discussions of the subject.

It has become evident, however, that the spread of this idea is threatening to reduce public support of scientific work, and in particular, through certain codes of the N.R.A., to stifle further technical improvements in our manufacturing processes. Either of these results would be nothing short of a national calamity—barring us from an advanced state of knowledge and standard of living and soon placing us at an economic disadvantage in respect to foreign countries

[1] A symposium on "Science Makes More Jobs" presented at a joint meeting of the American Institute of Physics and the New York Electrical Society at the Engineering Auditorium in New York on February 22. The address of Dr. Coolidge was broadcast from Schenectady by the National Broadcasting Company.

[2] A letter addressed to President Karl T. Compton, chairman of the American Institute of Physics, on the occasion of the symposium.

who have not let themselves be swayed by such a short-sighted point of view.

Consequently the New York Electrical Society and the American Institute of Physics are combining in a national service to combat this insidious and dangerous propaganda. They do not, of course, hold that scientific and technical advances have not brought difficulties, like social growing pains. But they strive to prevent us from killing the goose that lays the golden eggs, just because some of these eggs happen to be tarnished. They would advocate careful attention to polishing the eggs and encouraging the goose to lay more of them. In other words, they advocate intelligent and effective attention to remedy each social and economic difficulty as has accompanied the advance of science, and at the same time they advocate the further advancement of science and its applications for human welfare just as vigorously as possible They do this because the effects of science on human welfare are preponderatingly good and beneficial.

Now we might select any or all of the effects of science on human welfare as the chief point of our discussion tonight. We might, for example, call attention to the effects of medical science. Where would we be to-day without medical science, which has one by one eradicated or brought under control those diseases which used to plague mankind and occasionally to decimate his numbers? Before the days of science these were thought to be the results of the displeasure of gods and demons. Where would we be to-day without the sanitary engineer who safeguards our milk supply and provides a safe and plentiful water supply and disposes of our garbage? In India, where science and engineering have not taken hold, garbage is handled entirely by human hands, by that group who constitute the caste of "untouchables." They are "untouchable" because they carry filth and disease. We might, for example, call attention to modern science in communication and transportation Would any one like to go back to the days when the only communication was mouth to mouth or by post-horse mail carriage, and the only travel was by foot or horse or crude canoe? Would you like to give up the comforts and conveniences of your modern home, or the thousand and one things which add interest and pleasure and safety to life, which are products of science?

Think for a moment where we would be if our ancestors, alarmed by the progress of science, had taken steps by codes or by public sentiment to stop its progress! You now would be lacking in these things which I have mentioned. And if we, in this day and generation, act to stop science, our descendants will similarly miss the corresponding new advantages which they might otherwise have.

Do not be tempted to think that we are now in a unique position, that these social and economic problems have been suddenly thrust upon us by science, or that science has done what it can for mankind and had better stop. Back in ancient Rome the labor unions were struggling with hours of labor, wages, scab labor just as we are to-day. Back in 1600 Bacon described our present economic and social problems and anticipated some features of the New Deal with remarkable accuracy when he wrote:

> The first remedy or prevention is to remove, by all means possible, that material cause of sedition whereof we speak, which is, want and poverty in the estate (state); to which purpose serveth the opening and well-balancing of trade; the cherishing of manufactures; the banishing of idleness; the repressing of waste and excess by sumptuary laws; the improvement and husbanding of the soil; the regulating of

prices of things vendible; the moderating of taxes and tributes.

Forasmuch as the increase of any estate (state) must be upon the foreigner (for whatsoever is somewhere gotten, is somewhere lost), there be but three things which one nation selleth unto another—the commodity as nature yieldeth it, the manufacture, and the vecture, or carriage; so that, if these three wheels go, wealth will flow as in a spring tide.

And it cometh many times to pass, . . . that "the work and carriage is worth more than the material," and enricheth a state more; as is notably seen in the Low Countrymen who have the best mines above ground in the world.

Above all things, good policy is to be used, that the treasures and monies in a state be not gathered into few hands, for otherwise, a state may have a great stock and yet starve, and money is like much, not good except to be spread

That great human benefactor, Pasteur, had a grasp of the truth when he wrote: "What really carries us forward is a few scientific discoveries and their applications."

Those in charge of this meeting, however, have chosen not to try to handle the whole field of science and its effects on society but to concentrate primarily upon just one aspect of these social effects, namely, the effect of science upon employment. This is a very live issue in these days of unemployment. It is here that a misunderstanding of the effects of science are likely to be most dangerous, because of possible political influences. Let us therefore consider very briefly what these effects are.

We will immediately admit that technological advances frequently result in labor-saving devices which throw large numbers of men and women out of work. This is distinctly unfortunate. Its evil effects can be mitigated by wise handling of these new devices; as, for example, the American Telephone and Telegraph Company has handled its introduction of automatic switching so as not to throw employees out of work.

But the other side of the picture is immensely more significant in that the major result of science is the creation of entirely new industries which cater to new human desires, and which not only create a multitude of new jobs but which increase the per capita productiveness of men so as, first, to permit of an increasing population which is not limited by starvation and misery and, second, to reduce the hours necessary for men to labor to produce their necessities, and in this way to give them their opportunity to appreciate and experience some of the better opportunities of living which formerly were available only to those of wealth or of politically favored position.

Let me give a few examples of what I mean: Two years ago was celebrated the centennial anniversary of the discovery of the principles of electromagnetism which underlie practically all the modern electrical industry. According to the 1930 census there were in this country about 360,000 persons employed in the manufacture of electrical machinery and equipment, and about 676,334 people employed in the distribution of electrical materials, exclusive of the field of communication, namely, the telephone, telegraph and radio, which contribute in addition an immense number of workers.

Previous to the days of the automobile the 1900 census lists 976,000 individuals employed in the carriage and wagon industry, as manufacturers, drivers, draymen, livery stable managers, blacksmiths, etc. Thirty years later, with the advent of the automobile, based on innumerable scientific discoveries and engineering developments, the census lists 2,409,394 individuals engaged in this industry, exclusive of those involved in oil production. These figures have been corrected to allow for the increase in general population in the same interval. They show that while the advent of the

automobile produced technological unemployment among carriage and harness makers, yet the net result for labor has been a 250 per cent. increase in the number of jobs.

We frequently hear a great deal about the advent of labor-saving machinery on the road which has thrown out of work many men who would otherwise be employed in road construction. An amusing incident in this connection arose a couple of years ago in one of the state legislatures in the discussion of a public works bill for road construction. An amendment was offered to this bill providing that no labor-saving machinery should be used in the construction. The heated discussion of this amendment was brought to a close by the argument of *reductio ad absurdum* when a member of the legislature proposed a second amendment to the effect that laborers should be armed only with teaspoons in order that the number of jobs might still further be increased. What are the actual facts? Again corrected for increase in general population, the twenty years from 1910 to 1930, which witnessed the development of most of this labor-saving machinery, show an increase in the number of employees in road construction and repair from 203,000 to 339,000 individuals.

Such examples might be cited almost indefinitely. I would simply ask the question of where and when our serious unemployment problem should have struck if thirty years ago, to restrain technological unemployment in the carriage and wagon industry, legislation or codes had been enacted which would have inhibited the development of the automobile industry. Such an action would have eliminated the source of income which now supports about 10,000,000 people of our population.

I believe, however, that the argument can be made more fundamental even than this. Man has an irrepressible curiosity for new knowledge. This is the fundamental basis and urge for scientific work. Man has also an irrepressible desire to use his knowledge for the accomplishment of his desires. This is the basis of invention and of engineering. These, I believe, are so fundamentally a part of human psychology that they can not be fettered, though their free exercise may of course be hampered or, on the other hand, be encouraged. The early Egyptians who discovered that a wheel driven by the current or by oxen could lift up water from the Nile for the irrigation of his fields did not worry because this invention relieved him of the job of carrying his water by hand. He simply took advantage of this invention to increase his range of interests and activities in other directions. He cultivated more land, he experimented in early science, he built monuments which he could not have done had he toiled morning to night carrying water by hand. Similarly, I believe that in the last analysis the extent of man's employment is governed by man's inherent desire and urge to do something. If science can relieve him of the more routine tasks, he is free to turn his attention to other things which excite his curiosity or satisfy his desires. In the last analysis, therefore, I believe that science simply increases man's power and the range of his activities. Most certainly, however, both theory and experience prove more conclusively that science has made jobs, not taken them away.

SCIENCE AND INDUSTRY

By Dr. FRANK B. JEWETT
VICE-PRESIDENT OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY,
PRESIDENT OF THE BELL TELEPHONE LABORATORIES

I AM a bit embarrassed, because Dr Compton has upset the cards I had expected to be at the end of the procession and had assumed, as I think I had a right to assume, that Dr Compton and Dr Millikan would cover substantially all the grounds to be covered, and that I would come in at the end to give a few concrete illustrations in support of their theses. But by their having changed the order of the proceedings, I will have to do the best I can Both Dr Millikan and Dr. Compton, I think, as you will find, have very carefully prepared their talks I did not I assumed I would have a good deal of latitude

This allegation, that science has shot its bolt and that there should be a holiday on scientific research, of course, is nothing substantially new. Some of us have been hearing this thing for a good many years, but it has reached its crisis in this economic depression That it is a false assumption, I think is quite easily demonstrable, if one is willing to look at things in somewhat of a broad prospective. And if you look at it this way, you may be able to prove to your own satisfaction that scientific research has increased, rather than decreased, employment.

It has been my lot in life to be a director of industrial research and to see something of its workings—to know about its workings—and to know a bit about the application of science in various industries. Possibly because I am a bit of a philosopher, partly because it is my privilege to be interested in science, and partly because I was asked, some three or four years ago, to deliver a paper at the semi-centennial of the American Bar Association on a review of scientific progress for over fifty years—I began to look into this question of what science had really done—what applied science had done to affect human living.

One of the first things which appears to be of first importance is what has happened in the Western world in the last thirty-five years or so, in comparison to what happened in the rest of the world, relatively Let us go back to the period of time in the Middle Ages—or later—even up to the end of the eighteenth century. What you find is that goods were produced similarly in all parts of the world and that consequently scientific progress was about the same throughout the world

Then something happened—at about the beginning of the nineteenth century—in the Western world, which upset existing conditions That something was the introduction in the western society of science—and the furtherance of the scientific principle in living conditions.

During the nineteenth century, and more importantly, the first part of the twentieth century, that influence has grown and what has been its result is that it is the only major factor which has done more to correlate the markets of the Western world to those of the rest of the world Consequently, if scientific progress is not the sole cause of whatever has happened to strengthen world relations, it is the major factor in changing existing conditions. During this period of time, the population of the world has increased enormously. More people have been added to the world's population in that short period of time than in any preceding time—and they have been added in the very places

where science has found its work, in the Western world, in America particularly, and in Japan, the only one of the Oriental countries which has applied science.

Now to the question that science has reduced employment. It has greatly increased employment because it has increased the number of people gainfully occupied in its various aspects. Further than that, it has unquestionably increased the pleasure and ease of living in the sphere in which it has been operating. So much for the "look-see" at the situation.

Let's get down now to a little bit more specific proof of what science has done—is capable of doing—is capable of doing in the future. It has assembled the material achievements of the last hundred years and it particularly has assembled the achievements for us in the act of living.

Let us see what progress resulted from the advance in the use of science in industry. At the time of the Centennial Exposition there was no telephone system, no electric light or power industry. There was no automotive industry. There were no aeroplanes—nothing which involved internal combustion engines. There were no chemical industries, which have grown up in the last recent years. There was no motion picture machine, no talking machine, no radio, no picture transmission. We can get up a list of things that are extremely important to-day, which did not exist at all at the time of the fair. Out of these have been built huge industries—the greatest outside of agriculture, which have given employment to untold thousands.

One thing which this exposition did and which they did not expect it to do was that it acted as a great inspiration to the youth of the country, and the result is a vast expansion to the application of science in an enormous number of industries and activities which had not so been benefited before.

Dr. Compton has indicated that in normal times there are one-half million people employed, in the operation of the telephone business in this country. If we subtract what we have learned through scientific research in the last fifteen years, if we go back to the close of the world war, the utility of the telephone as an instrument in our social and economic life would decrease so much as to cut the magnitude of its force to less than half of what it is now. You would have no radio broadcasting, no radio talking pictures—you would have none of these industries which has grown up within recent years and which have given employment to large numbers of people directly employed, or those indirectly employed in these industries which resulted from scientific research and development.

Of my thirty years of industrial research activity, I cannot find a single instance where a scientific achievement has resulted in a reduction in employment. In nearly every case, more work has resulted and there has been a betterment of living conditions. It is true, as Dr. Compton has pointed out, that benefits of scientific research flow to all classes of the population, and even the least competent of the people find themselves a step further from the starvation line.

If one is willing to look at facts in broad perspective, it seems to me that one can not but see that history, in the last 150 years at least, has proven that scientific research, applied to the forces of life, has resulted in better living conditions and an increase of employment for people who are gainfully working in scientific industries. I think that any argument to the contrary is based on complete ignorance, or based on a too-narrow survey of specific, unrelated facts.

THE SERVICE OF SCIENCE

Dr. ROBERT A. MILLIKAN

DIRECTOR, NORMAN BRIDGE LABORATORY OF PHYSICS, CALIFORNIA INSTITUTE OF TECHNOLOGY

My grandad notes the world's worn cogs
And says we're going to the dogs;
His grandad in his house of logs
Swore things were going to the dogs;
His dad amid the Flemish bogs
Groaned ugh! We're going to the dogs;
The cave-man in his queer skin togs
Snarled Gad! We're going to the dogs;
But this is what I'd like to state
Those dogs have had an awful wait.

If any of my auditors to-night doubt that the common man, called above "my grandad," is vastly better off here to-day in depressed America than he has ever been at any other epoch in history, I beg of you to begin to read carefully a bit of that history—or if you haven't time for that, then to make friends with some historian and pump him on the living conditions of the common man in any preceding age as compared with those existing right now in the midst of the world's greatest depression.

If you can not take time to acquire the knowledge which comes from one or the other of these procedures, then all I have to say is you could not take even a bachelor's degree from the California Institute of Technology, for every one of our graduates gets four straight years of English and history in the broad sense of those terms, and that because scientists and engineers who are to be the leaders of the future can not possibly lead wisely unless they have a good deal of familiarity with what man has thought, achieved and *discarded* in the past—also of how his economic and social life has evolved into the present. If that kind of knowledge and background had been the lot of some who have written and talked voluminously during the past five years, the world would have been spared the term "technocracy" and the muddy mess of verbiage which has grown up around it to confuse the public mind.

If you haven't even time for either of the foregoing procedures, then let me ask you at least to take ten minutes to read a brief article by Henry M. Robinson published in the December number of the *Reader's Digest* entitled, "No Time Like the Present." Its simple statement of historic facts will be an eye-opener to some of you.

In suggesting that you read it, I am not trying to lull any one into contentment with things as they are. I am merely trying to start my address with the evidence that enormous progress *has been* made, so that I may be in position to attempt to show how and why it has come about. It is my hope that in this way the muddy stream of public thinking may be somewhat clarified and the road to future progress made more clear.

Let me first quote Mr. Robinson's conclusions from his historic studies. He says, "For all its chafings and imperfections our age is superior in security, comfort, leisure and economic rewards to any other period or condition of life that ever existed in this sweating tear-drenched world." Or again, "In terms of political justice, economic cooperation, health, happiness and human sympathy there has, as yet, been no time like the present."

But I hear my friend Mr. Upton Sinclair and other equally "clear thinkers" of his school saying, "How can Mr. Robinson make ridiculous statements like that about the United States which has developed under a system that has now, as the depression shows, completely broken down?" Of course the answer

to that statement is that there isn't any evidence that the depression shows anything about it; that since depressions galore have happened under all systems we shall have to take a longer look before we can draw any sound conclusions; and when I do that a quite different answer seems to me to stand out with great clearness from the pages of history. For there, one sees great stretches of time in which with many depressions and revivals within them there has yet been on the whole a continuous upward swing. Such a period apparently lasted for thousands of years in Egypt before decay set in. In both Greece and Rome it lasted for hundreds of years before dissolution. In England there seems to have been a rather continuous upward trend for a thousand years and she is going strong yet. And in America we think we have been on the upgrade for 200 years and we are far from being willing to admit that we are yet done.

As I read history, wherever and whenever conditions have been such as to give opportunity to many individuals to develop industry, thrift, self-reliance, resourcefulness and adventurousness—in a single phrase, wherever and whenever the average citizen has been given the opportunity and the stimulus to achievement, there and then you have had an age of Pericles, of Elizabeth, of George Washington, of Victoria, of Theodore Roosevelt. Note, too, that industry and thrift underlie it all, for the adventurer cannot set forth into any unknown land, geographical, commercial or scientific—and it is that kind of adventuring alone that makes for progress—until he has accumulated enough provisions to support him in his expedition. There you have the whole of the theory of so-called capitalism. If I read history aright, any system or set of conditions which furnishes wide opportunity for individual initiative, which inspires many people to thrift and to adventure, makes for progress, while any soft paternalism which kills that spirit makes for decay and retrogression; for a nation is obviously nothing but the composite of the individuals that unite to make it. I have shuddered recently to hear men in high place in American life belittle those old-time virtues of industry and thrift, the discovery of which as fundamental virtues is probably the greatest achievement of the human race to date, transcending in importance all our scientific discoveries put together, for it has underlain them all and made them possible. Once lose that attitude and we are gone!

This doesn't mean that I am arguing for a *laissez-faire* system or that I disapprove regulatory, governmental legislation of the proper kind. In my judgment *laissez-faire* and state socialism have both been historically found to have had the words *mene, mene tekel upharsin* ("thou hast been weighed in the balance and found wanting") written upon their walls, and we must therefore take some intermediate course. I am merely trying to lay down some general principles which, if I have learned the lessons of history aright, must guide that course. Our American public utility system, for example, represents, as I see it, the Anglo-Saxon's genius for finding an intermediate course between two extremes, *laissez-faire* and government ownership and operation of industry, both of which have miserably failed. It has of course been subject to abuses, but I look for their correction and the extension of the underlying principle.

But what has all this to do with science and its applications in the modern world? Everything! For practically the whole of the modern world, governmental and otherwise, is built on science and its applications, and it is the spirit of industry and thrift and adventure that has created modern science.

Just now in the midst of this depression certain voices are raised which counsel us to soft-pedal on science, at least until the rest of the world has caught up. I therefore propose to consider now how much wisdom there is in this counsel.

Before treating it seriously, however, let me first smile with you over the extraordinary adaptability of a depression to the needs or the purposes of every demagogue as well as every sincere but unseeing reformer to exploit his own particular nostrum and also, though sometimes unconsciously, his own self-interest. There are quite as many causes of the depression as there are people who have different axes to grind. Quite oblivious of the fact that the depression has been world-wide and the upswing from it equally world-wide and therefore necessarily essentially independent of our local issues, Democrats and Republicans alike, and some normally intelligent ones, too, blandly charge their opponents with all the ills and take credit to themselves for all the goods. Such is the way of politicians and always will be as long as there is an ignorant and undiscriminating electorate to which they must appeal.

But now leaving behind us childish things, for what is science actually responsible in this American civilization of ours? Let me first give to that question the answers upon which there will and can be no essential disagreement. Science and its applications have so increased the efficiency of labor that here in the United States we produce more of the fundamental food-stuffs, clothing, building materials and fuels than we, just now, know what to do with; and in spite of the present jam in our social machinery which we call the depression the great bulk of all this produce goes now, and always has gone to the common man, that is, to labor. So nearly is that true that any economist will tell you that the standard of living in the different countries of the earth is in general directly proportional to the total productivity of these countries per inhabitant. That is why in spite of the depression the standard of living here has remained relatively high and there has been no appreciable starvation, while in Russia, where the opportunity for, and stimulus to, individual effort has been removed through state paternalism, not less than five million people, according to Whiting Williams, starved to death last year, and also where he says that the well-being of the common man is incomparably lower than it is here when at its worst.

In the second place I need to bring forth no figures to convince anybody that the productivity of labor, brought about by the applications of science in America, has opened up to the common man the opportunities of leisure such as he has never known at any other time or place. When in history has a 40-hour week for the common laborer ever been heard of before? And what glorious vistas of a heretofore undreamed-of-civilization—civilization for the many instead of for the few resting on the backs of the many, as was the case in Athens—can be seen ahead if we can only teach the common man to use that leisure for his self-improvement instead of for his deterioration as he does so often now! This is where our secondary educational system has its greatest opportunity.

About the foregoing contributions of science to our civilization there will be no controversy. But now comes the question upon which the public mind has become much confused because of men who do more talking as I think than they do thinking. These men say "science is responsible for unemployment and therefore for the depression. Science through labor-saving devices is all the time destroying jobs by means of which

men live." The answer to this charge is that it is true, but like most delusions it is only half the truth and therefore fundamentally false. The other half is that every labor-saving device creates in general as many, oftentimes more, jobs than it destroys, and the new jobs are in general better for the individual affected, and much better for society as a whole than the old ones. Labor-saving devices do not in general destroy the jobs that demand intelligence. They cannot do it. The heavy, grinding, routine, deadening jobs are the ones that machinery destroys. In a word, the world's drudgery that used to be done by human slaves is now done by soulless, feelingless iron slaves, and the human is freed for the more interesting jobs of building, running and keeping in order the machines of his creation, or of rendering the public service which the existence of these machines has made necessary. Even if these occupations do not employ all the displaced labor the rest of it ministers to the educational wants that society can now embark upon because of its increased economical well-being.

The progress of civilization consists primarily in the multiplication of human wants. If you want a stagnant civilization you have only to destroy the influences that cause these wants to multiply. The automobile industry has become a largely mechanized one and has destroyed the Studebaker buggy business. It uses still a certain number of operatives with plenty of leisure and good pay to tend its machines—and don't for a minute pity them—but look rather at the hundreds of thousands of good jobs that it has created in garages and service stations. It takes a brain to be a trouble man in a garage—as interesting a job to me as exists on earth—and the service station men! Why, they have improved the manners and the courtesy and the consideration of the American public more than all the colleges in the country put together. We don't call them "professor" yet, but they are doing quite as big an educational job as are most of us professors.

This is but one illustration, but it is typical of the whole process. Taking the long-range view, not the short-range one, I have no hesitation whatever in saying that there is no such thing as technological unemployment. By what authority do I say that? By the authority of the official census of the United States. This lists every decade the percentage of the population "gainfully employed." This was 34 per cent. in 1880 and almost exactly 40 per cent. in 1930—a depression year—and it had shown a steady increase decade by decade, save for a negligible drop from 1920—when war conditions were still on—to 1930. In other words, in this precise period in which science has been applied most rapidly to industry the percentage of our population living by means of jobs has continually increased—comment enough on the soundness of the judgments of those who attribute the depression—which seems to me to be in fact a purely social phenomenon—to technological unemployment.

One more point and I am done. The idea that it might be wise to let the development of the natural sciences wait until the social sciences have caught up is another idea that in my judgment rests upon very muddy thinking. Why? Because it is the change in the conditions of living brought about by developments in the natural sciences that very often makes possible an advance in the social sciences. For example, if we had found no other way of propelling our war ships against the enemy than that which was open to the Greeks and Romans, namely, by chaining human slaves to the oarlocks and lashing them to their task, it may well be doubted whether we should not be doing to-day just this thing that the Romans did 2,000 years ago.

Again, when the cause of yellow fever was discovered by science an enormous social advance became for the first time possible, or when Lauritsen first perfected four years ago a million and a half volt x-ray tube and started with Dr. Seeley Mudd that elaborate and highly scientific research into the effect of such radiation upon deep-seated cancer, the essentially social struggle against one of mankind's greatest scourges entered upon a new phase.

Again, the social scientist looking at war from the historic standpoint declared at Boston last December that hoping for its elimination was as silly as hoping for miracles. He forgot that the developments in the natural sciences are rapidly rendering it inimical to national interests to embark upon an aggressive war. So soon as the jingoes have seen that light or have ruined their nations by shutting their eyes to it, another social miracle will have happened. Once stop the development of the natural sciences, and the chief stimulant to the progress of civilization disappears and the social sciences will begin to stagnate also.

Let me give you just one further illustration that is very near at home for me. The new big Douglas passenger plane has been for long months past in the Daniel Guggenheim aeronautical laboratory at the California Institute, where, according to the official statement of the Douglas Company, 35 miles of cruising speed was added to its performance, 195 miles of cruising speed—15 hours from Los Angeles to New York—(it was actually 13 hours last Monday)—changes more than one aspect of both the transportation and the combat problems. Political manipulation may destroy for a time the social effectiveness of such an advance, but it can not be destroyed for long. Men may come and men may go, human laws may change with the whim of legislators and their supporting public opinion. That is the sad thing about social progress. It may, and often does, go backward instead of forward; but that part of it that rests upon changes in the life of man due to physical discoveries and developments remains immune from political and all other human influences, for its unchanging laws are written in the heart of the universe and progress here is the sure possession of all the ages yet to be. Perhaps the natural sciences are themselves the most enduring and the most effective of the social sciences. Let that thought sink deep into the mind of him who would stay their progress.

SCIENTIFIC DEVELOPMENTS AND THEIR APPLICATION

By Dr. W. D. COOLIDGE

DIRECTOR OF THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY

A QUESTION frequently asked by visitors to our laboratory is, What will the future bring? Of course we make no pretense to gifts of prophecy, but the question is not a foolish one, for the closest one can come to an intelligent guess is by studying current scientific developments and their possible applications.

We all know that our present civilization is based on engineering. To realize how completely this is so, we need only to imagine what would happen to any modern city if all products of engineering were suddenly wiped out, leaving the city without electric light and power, with no motors to drive its machines, no pumps for its water supply, no trolley

cars, buses or automobiles for transportation, no telephones for communication, no railroads for bringing in food or for shipping the city's products. That city would survive about as long as a snowball on a hot pavement in July.

So this much we may safely predict about the future. Whatever life may be like fifty or a hundred years from now, we may be sure that the comforts, conveniences, conditions of labor and of recreation—in short, all that determines the standard of living, will depend on the engineering developments that will have occurred in the meantime.

Now engineering is simply applied science. Just as the engineering of today sprang from scientific researches of the past, so the engineering of the future is being shaped by the scientific researches now in progress. That is why the best guess as to the future may be formulated only by a study of recent scientific developments and their possible applications.

There are two things that must strike any student of current scientific progress—the constant acceleration of that progress and the closeness of its approach to the fundamentals of the universe.

In each generation there are those who think that so much has been accomplished that the end of progress is near. I believe it was more than fifty years ago that a commissioner of patents resigned because all worth-while inventions had been made and the Patent Office would soon be useless. It was less than fifty years ago that an eminent physicist said that all the fundamental discoveries had been made, and yet, almost as he said it, a series of discoveries was beginning which has resulted in far greater progress toward an understanding of fundamentals than had been made in all the previous history of man.

It is true that the most obvious things have been discovered, but the army of scientific workers has enormously increased and new weapons of marvelous range and accuracy have been developed for attacking the unknown, so that although the terrain grows more difficult, the forward drive is steadily gaining in momentum. Great as has been the progress of the past fifty years, we may be sure that it will be far surpassed in the next fifty.

The existence of our laboratory has been almost contemporaneous with the development of the newest field of physics—electronics. The electron was first identified by J. J. Thomson in England less than five years before our laboratory was founded. Since then we have taken active part in the development of the present great variety of electron tubes which are already serving man in multitudinous ways. We have the radio tubes which made broadcasting possible, creating a new art which gave employment to tens of thousands and entertainment and instruction to millions; we have the tubes which gave a voice to the motion picture and so increased the range and potentialities of the cinema art; we have the improved x-ray tubes which have so strengthened the hands of the medical profession in its war on disease as to have saved many lives and much human suffering; we have tubes which are producing light more efficiently than our best Mazda lamps; we have the tubes which, in industry, are beginning to take over many control jobs and inspectional jobs, doing them better and quicker than a human operator, and thereby carrying on the work, begun by the electric motor, of relieving labor from drudgery, heightening its efficiency and thereby raising standards of living; and we have the supersensitive tubes which are enabling astronomers to pry into secrets in the far depths of space hidden from the eye and from the photographic plate.

Thus physical research, through its discovery of the electron, has added to human enjoyment, decreased human suf-

fering, raised the standard of living and supplied new and powerful tools for extending scientific knowledge.

The same forty-year period has seen corresponding advances in other fields. Medical research has gone far toward bringing under control such diverse and dire diseases as tuberculosis, diabetes and leprosy. We may confidently expect that in the next forty years such scourges as cancer and pneumonia will lose much of their terror.

So the new discoveries in physics will surely bring, in ways we can not definitely foresee, new and great potentialities to civilization. Those potentialities, properly applied, should bring to all mankind new products, increased efficiency, shorter working hours, more pleasures, comforts and conveniences, better health, all that goes to make life richer and happier. If our economic system is not flexible enough, nor our statesmen and economists wise enough to modify it, so that these potentialities may be realized without unemployment and suffering for many during the inevitable swift transitions, it will be a disaster. But that disaster can no more be blamed on the scientist or his researches than the chemist can be blamed if his discoveries are diverted, by the crimes of political leaders, from their beneficent potentialities in the arts of peace to the wholesale destruction of human life in war.

We should not worry about the advances in natural science. They hold untold benefits for man. Our anxiety should be for the social sciences which are lagging far behind and which only now are beginning to awake to the fact, known to the physical sciences since Galileo's day, three hundred and fifty years ago, that there is only one road to new and certain knowledge—the road that is paved, not by theorizing, but by experiment.

NOTE: The following is an extract from a letter received from Owen D. Young, chairman of the board of the General Electric Company, on the occasion of the symposium: "The notion that science and technical development have resulted in unemployment and financial panic is a characteristic of a depression period In such periods there is always a search for a devil who caused it Of all the devils sought in these times of anger and despair, the attack against science is least justified. It not only was not the devil which caused the depression, but it is the most promising angel to lead us out of it

"If our production were standardized to-day, which so many advocate, and the work distributed among our people, the result would be to focus all of our ingenuity and energy on reducing the cost of the standardized thing. That inevitably would reduce the labor content, and so the work to be divided among our people would surely grow less and less

"There is no hope in that direction. Replacement would only exist against physical wear-out, and that until now has been only a small part of our replacement program. In America obsolescence—not wear-out—has been the thing which has kept our people at work and at the same time has produced more and better things at less cost for us all to use.

"Science is the mother of obsolescence, and to the extent we paralyze it we will limit employment, wages and our standard of living."

RACING CAPACITY IN THE THOROUGHBRED HORSE

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PART II. THE INHERITANCE OF RACING CAPACITY

The Development of a Mathematical Formula by which Nature Transmits Racing Capacity from One Generation of Thoroughbred Horses to the Next

The Thoroughbred or running horse has been bred for more than 300 years by some of the world's most skilled breeders of domestic animals. Substantial resources have been placed at their disposal. The basic aim in this breeding has been to increase the speed of the running horse without sacrificing its ability for sustained effort in distance-going and for weight-carrying. Nothing is more soundly demonstrated in practical breeding than that racing capacity tends strongly to run-in-the-family, and that heredity plays a major rôle in its production. What rules, then, govern its inheritance?

Throughout the present researches much consideration has been given to past investigations of the breeding of the Thoroughbred horse, particularly whenever such studies touch on the inheritance of racing capacity. These studies have supplied a wealth of material, but too many of them have assumed a theory of some sort at the start, and then proceeded to bolster it up by selected evidence—the method of special pleading but not of scientific investigation. The only points upon which all investigators—biological and mathematical, practical and theoretical—have agreed are that racing capacity is a very complex quality, that it tends strongly to run-in-the-family, and that care and training of an exacting nature are necessary to bring out inborn capacity. Obviously, our present task is to find out more exactly just how this inborn element runs-in-the-family. In this work the order of precedency must be facts first and theory second. Accordingly the present investigation will not begin with any theory. It will first seek only the most accurate mathematical picture which can be found for the behavior of Nature in transmitting racing capacity from one generation to another.

Finally, in possession of an accurate yard-stick for the measure of racing capacity in the individual horse we are ready to examine the basic genetic problem: "Given a stallion and a mare, and a group of their nearest blood-kin, each with a definite racing record—each record in terms of sex, age, weight-carried, distance-run, track condition, trueness of the running, and speed—what sort of racing capacities will their offspring possess?" That is, "What is the probability that a pre-selected one of their foals will possess a racing capacity within definitely pre-selected limits?"

Nature of Racing Capacity and the Mendelian Try-Out

Racing capacity in the running horse involves nearly every natural resource of the animal. It is a complex function which calls on physiological and nervous quality, together with the entire ana-

tomical structure of the individual. It is thus, as nearly as almost any quality of which we can conceive, a function of the organism as a whole. Consequently, because it depends upon the whole organism, it is in the horse the result of the somatic development of the thirty pairs of chromosomes, each doubtless with many hundreds of genes. Then racing capacity, far from being a "thing present or absent," or based upon a single gene, is, in its hereditary aspect, more probably based upon the developmental interaction of many thousands of genes.

Practical breeding has contributed substantially to determining the essential genetic nature of racing capacity. The rules by which Nature governs the inheritance of this very definite functional entity in the Thoroughbred horse are not the rules which govern the segregation and the additive recombination of a few genes in the manner followed when the Mendelian formula is applicable. In Mendelian genetics a definite somatic trait—functional or anatomical—is the recognizable developmental product of one or more definite genes in the chromosome. These genes are present in certain alternative combinations. Each such combination results in a definite somatic phase. These facts, together with the supporting discovery by the cytologist about the mechanical behavior of chromosomes and chromomeres, have constituted the principal foundation stones of modern genetics. Random segregations and recombinations of chromosomes in "building the gametes for fertilization," and the facts of fertilization itself, give the mechanical basis for predicting the mathematical probability that the offspring will possess a particular set of somatic traits. Thus Mendelian prediction is always based upon the distribution of the subject-trait among the antecedent near-kin, plus the idealized picture of the behavior of the gene and its chromosome.

But, while this is a most fundamental principle of modern genetics, it is not possible in genetic analysis to apply it to most of the qualities which are useful in actual plant and animal breeding. Nor is the coördination of genetics with embryology, with eugenics or with evolution often possible when genetics offers only the "tools of gross chromosome behavior."

As earlier stated, Mendelian genetics has correlated its phenomena so closely with sound cytological explanation, that good procedure in the genetic study of any specific quality, whether structural or functional, requires that the Mendelian formula be tried out, and that the cytology of the matter be gone into. Accordingly these researches many times examined carefully the possibility of interpreting the observed phenomena in terms of the Mendelian formula.

As a preliminary research the services of Dr. Theophilus S. Painter were secured to make a careful study of the chromosomes of the Thoroughbred horse. He found the haploid chromosome number to be 30, and the usual mammalian x-y sex-type. This was a definite contribution to the cytology of mammalian genetics, but it contributed nothing directly to our ability to predict racing capacity in offspring.

Most studies in heredity look to the development of a prediction-formula. The present researches on the Thoroughbred horse are no exception. We must then compose the correct mathematical picture of how Nature behaves in transmitting racing capacity from one generation to another. If we could tie-up such a prediction-formula with the mechanism of heredity, as shown by the cytologist in his microscopic study of germ-cells and chromosomes, the study would be all the more satisfactory. But whether we can do this or not, we must first have a correct mathematical picture of "how it is" before we can seek hopefully to find out "why it is."

A structural quality like stature in

$$P_{\text{sel. BH} \pm 2.5} = \left[\begin{array}{l} 1.5 \text{ when } \dfrac{21.47\,(BH-2.5)}{.1386\,FI+4.899563} < 113.1199 \\ \text{or} \\ .5 \text{ when } \dfrac{21.47\,(BH-2.5)}{1386\,FI+4.899563} > 113.1199 \end{array}\right] \cdot \left[PI \text{ for } \left(\begin{array}{ll} \dfrac{113.1199 \sim \frac{21.47\,(BH-2.5)}{1386\,FI+4.899563}}{24.0814} & \begin{array}{l}\text{when first term of} \\ \text{numerator} > \text{second}\end{array} \\ \text{or} & \\ \dfrac{113.1199 \sim \frac{21.47\,(BH-2.5)}{1386\,FI+4.899563}}{8.5834} & \begin{array}{l}\text{when first term of} \\ \text{numerator} < \text{second}\end{array} \end{array}\right)\right]$$

$$\left[\begin{array}{l} \sim \text{ when both } \dfrac{21.47\,(BH-2.5)}{1386\,FI+4.899563} \text{ and } \dfrac{21.47\,(BH+2.5)}{1386\,FI+4.899563} \text{ are } < (\text{or} >)\ 113.1199 \\ \text{or } + \text{ when } \dfrac{21.47\,(BH-2.5)}{1386\,FI+4.899563} < 113.1199 \text{ and } \dfrac{21.47\,(BH+2.5)}{1386\,FI+4.899563} > 113.1199 \end{array}\right] \cdot$$

$$\left[\begin{array}{l} 1.5 \text{ when } \dfrac{21.47\,(BH+2.5)}{1386\,FI+4.899563} < 113.1199 \\ \text{or} \\ .5 \text{ when } \dfrac{21.47\,(BH+2.5)}{1386\,FI+4.899563} > 113.1199 \end{array}\right] \cdot \left[PI \text{ for } \left(\begin{array}{ll} \dfrac{113.1199 \sim \frac{21.47\,(BH+2.5)}{1386\,FI+4.899563}}{24.0814} & \begin{array}{l}\text{when first term of} \\ \text{numerator} > \text{second}\end{array} \\ \text{or} & \\ \dfrac{113.1199 \sim \frac{21.47\,(BH+2.5)}{1386\,FI+4.899563}}{8.5834} & \begin{array}{l}\text{when first term of} \\ \text{numerator} < \text{second}\end{array} \end{array}\right)\right]$$

FIG. 4. THE FORMULA OPERATIVE FORMULA FOR THE INHERITANCE OF RACING CAPACITY IN THE THOROUGHBRED HORSE

man, or a functional quality like racing capacity in the Thoroughbred horse, far from being based upon a single or a few Mendelian genes, is, as we have seen, doubtless the developmental end-product of a great many—possibly a thousand or more—genes. In the course of development these genes interact, some accelerating their fellows, others cancelling what otherwise would be high plus-effects in the individual. The resultant is that, keeping environment constant, the pre-selected individual offspring will possess the particular quality in an end-value somewhere on a scale ranging from very low to very high. Although such a quality may be definitely measurable, its constituent nature is vastly too complex to be attributable, in Mendelian fashion, to the additive combination of a few genes Geneticists can not yet dissect a single complex quality, much less any whole animal organism, into its constituent Mendelian genes. In such a dissection each gene would have to stand for a definite part played in the development of a quality—good or bad, structural or functional—of some sort. Doubtless, with a very few exceptions, each quality of use in practical breeding is based upon many genes, and each such gene, in turn, contributes, in some manner, to a great many—possibly hundreds—measurable structures and functions

Attempts to throw critically judged, and later accurately measured, racing capacities into classes, and to postulate one, two or three Mendelian units as the genetic basis for variation in transmitted racing capacity failed to give any consistent interpretation. It was necessary to strike out anew.

Formula for the Inheritance of Racing Capacity in the Thoroughbred Horse

Poetically a horse "has racing capacity or he has it not." But, in fact, racing capacity ranges continuously in different horses from B.H. = 0 to B.H. = 140—the latter just a trifle above Man o'War's rating. Granted that racing capacity in the individual horse depends upon the working out of a vast group of genes in the course of development, and that the quality of racing capacity is highly hereditary, the formula for the inheritance of racing capacity must read: "The Probability that the pre-indicated or random-selected foal of a particular sire and dam will develop a racing capacity within definitely named

FIG. 5. MATHEMATICAL MODEL OF THE FORMULA OF THE INHERITANCE OF RACING CAPACITY IN THE OFFSPRING OF THE 54 MARES OF THE MEREWORTH STUD. 1925–1930

The formula for the inheritance of racing capacity in the Thoroughbred horse gives the mathematical procedure to be followed in computing the distribution of offspring into capacity-range-categories The basis of prediction is called the Futurity Index. It is made up by stressing appropriately a number of the nearest antecedent blood-kin. With a given Futurity Index, or hereditary promise, the formula for the inheritance of racing capacity enables us to compute the probability that the foal with a given Futurity Index will fall within the selected racing-capacity-range. The formula is based upon how Nature has behaved in transmitting racing capacity from parent to offspring—"on experience"

Practically, the problem can be solved for any given Futurity Index by substituting the value of such Index and the value of the selected class-range in the formula and solving for P, or probability. The formula is rather long and descriptive but when reduced to definite FI values it is handled quite readily

Graphically the same values found in the formula can be picked off of the surface of the above pictured mathematical model. We set the indicators at the selected Futurity Index and at the selected B II. of offspring, then find the height at which the two pointers meet on the surface, then swing one of the pointers to the "probability post" where one can read off graphically the same values of P which one could find by solving the formula mathematically.

The summation of all probabilities one class-range apart for any given prediction-basis, or Futurity Index, must always equal one or certainty. That is, the foal of a given mating, if it races, will, by a probability of one, *i.e.*, certainty, possess some sort of racing capacity. This formula enables us to break up certainty into its constituent probabilities by capacity-class-ranges.

limits, as a function of the prediction index." In general terms the formula is

$$P = f\ (PI,\ OCR)$$

In this P = Probability; PI = Prediction index; and OCR = Offspring-class-range. Thus the task narrows down to "Just what prediction-index, just what offspring-capacity-range, and just what function?"

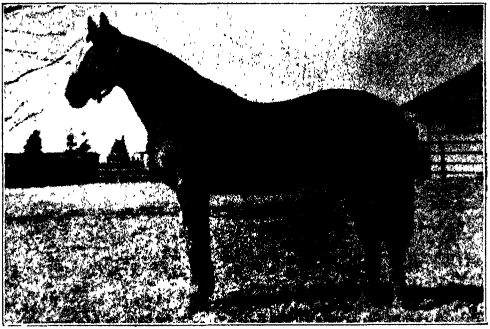
Fig. 4 gives in detail the operative formula for the inheritance of racing capacity; and Fig. 5 shows its mathematical model. This model is so constructed that it may be used for the graphical solution of the formula. One of the three Cartesian coördinates—fore and aft—represents the prediction-basis, another—right and left—the center of the offspring-class-range predicted, and the third—the upright coördinate—represents the probability that, when the selected value of the prediction-basis is used, the offspring will fall into the selected offspring-class-range. Set one of the model-pointers over the selected prediction-basis; set the other over the mid-offspring-class-range "predicted." Then adjust the two arms so their points will meet on the surface of the model. Then swing one arm-point to the vertical coordinate-scale, the point-height thus measures the probability that the selected value of the prediction-basis and the selected offspring-class-range will, in actual breeding, fall together.

The prediction-index is here called the futurity index, or F.I. It is composed entirely of racing capacity values of a group of the nearest blood-kin antecedent to the foal whose racing capacity is predicted. Each near blood-kin constituent of the prediction-basis is stressed or weighted the proper amount, determined by experience to give the most consistent series of predictions.

It must be remembered that the racing capacity of each of these kin is computed from actual race-performances. The real substance of the prediction in heredity, then, goes back for its elements to actual race-performance of the antecedent near blood-kin, with due consideration for sex, age, weight-carried, distance-run and speed attained, other factors being equal. For each individual kin, such a record thus duly computed is its real "past-performance."

Experience has shown that the nearest blood-kin—direct and collateral—constitute a sounder basis of prediction for racing capacity in the foal than can be worked out by tracing descent along a few dilute ancestral lines. That section of the near-kin index of the sire, or of the dam, which goes into the futurity index is called the breeding factor. Thus the breeding factor of the sire, plus the breeding factor of the dam, equals the futurity index of the contemplated foal. The prediction-basis, that is, the futurity index, is the hereditary promise of the foal. Such promise may be computed before the foal is born, or even before his sire and dam are mated. If the contemplated mating does not indicate a desirable hereditary promise, the actual mating need not be made.

In this prediction-basis or futurity index, the breeding factor of the sire is obtained by placing equal stress upon the racing capacity of his sire and of his dam—one sixth each, upon the racing capacity of the sire himself—one third, and upon the racing foals which he has already produced—one third for the group. Similarly the breeding factor of the dam is computed. Equal stress is placed upon the sire and the dam. Such stress-equality is purely empirical. But after many "trials and errors," it was found to constitute a very good prediction-index. A better prediction-index is, of course, possible both theoretically and practically. Studies are now under way, designed to find a theoretically correct stressing for antecedent near-kin in an index of this sort. The practical pur-



FAIR PLAY, CHESTNUT COLT, FOALED 1905, BY HASTINGS, OUT OF FAIRY GOLD

FI—116.68 RC—125 75 NKI—120.71 BF—61.25

FAIR PLAY WAS THE SIRE OF MAN O'WAR AND OF MANY OTHER OUTSTANDING AMERICAN THOROUGHBREDS. BY COMMON CONSENT HE IS RATED AS ONE OF THE GREAT SIRES OF THE BREED.

pose is to find a prediction-index which will make the mathematical model of the formula "very tall, steep, and narrow." For the present all computations of probability of a given racing capacity appearing in the offspring are based upon the Futurity Index, as above stressed.

While the above stresses in the futurity index have been used in the present formula, such stresses need not be the last word. The formula is flexible; with further research we can re-weight or re-stress the several near-kin until a new re-weighting or re-stressing does not produce a better prediction-result. The present unrefined formula is a basic tool or machine supplied with an "adjustment mechanism" for its own perfection; and the test for moving in the direction of truth is better prediction.

The prediction-technique herein worked out is called "ogive-regression-probability" It is so called because in the procedure which found the present operative formula of heredity for racing capacity in the stock sampled, these three principles were used First the futurity indices were ranged as an ogive, next the mean racing-capacity value of the offspring which each futurity index actually produced was plotted on the same scale. The straight-line fittings for these two series of data—futurity indices and the mean offspring values—show a typical biological regression. Hence the second term in the name of the present technique. The mean-offspring-value line is computed by analytics from the prediction-basis or futurity-index line. The straightened lines of the prediction-basis and of the

MAN O'WAR, CHESTNUT COLT, FOALED 1917, BY FAIR PLAY, OUT OF MAHUBAH

MAN O'WAR IS BY GENERAL CONSENT RATED AS ONE OF THE BEST THOROUGHBRED RACE HORSES WHICH THE BREED HAS EVER PRODUCED. BY THE PRESENT MEASURE OF RACING CAPACITY HE IS CREDITED WITH A BIOLOGICAL RACING CAPACITY OF 139.25.

mean offspring produced need not actually cross at the mid-value of the strains actually sampled; they only point toward a crossing which is the point of no regression for the particular breed-group. If this were the end of the problem, the solution would be relatively simple, but the regression line must be treated as a fluctuation center for offspring values. Here the third term of the name, probability, comes in, for it computes the likelihood that a given offspring will fall within a definite range, the range-center of which is a definite distance from this fluctuation center, measured on the racing capacity scale.

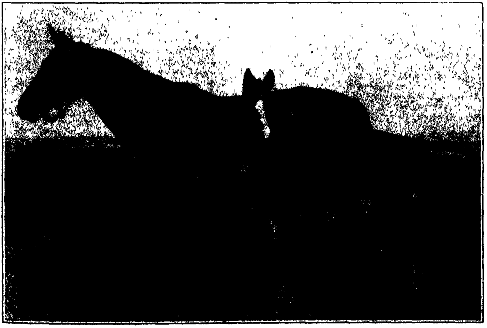
It is noticed in the mathematical model of the formula of heredity for racing capacity (Fig. 5) that the plus values of offspring show a sudden decline in frequency as the higher ranges are attained. This seems a reasonable phenomenon, for in striving to attain the higher levels we should not logically expect as many nor so great successes in the plus direction as we find failures in the minus direction. This expectation is here borne out by the mathematical

picture of how Nature actually behaves when breeders try, by rigorous selection, to improve the breed of the Thoroughbred running horse. This factor gives the skewed shape to the model (Fig. 5).

Overlapping Probability

Practically it happens, and theoretically it is by the present findings expected to happen, that almost any quality of Thoroughbred sire and dam will on occasion produce almost any racing capacity in the offspring. But, depending on the racing capacities of the foal's near-blood-kin, the probability that inborn racing capacity of a certain quality will be possessed by a pre-selected future foal is many times the probability that the same foal will possess a certain other inborn racing capacity. The present study of many Thoroughbred offspring attempts to show just how probable it is that a specific quality of racing capacity will be produced by a given mating.

The overlapping diagram (Fig. 6) is made by "telescoping" two cross-sections of the model (Fig. 5) of the formula, the cross-sections being made at each of two selected prediction-index values. That part of the cross-section probability curve for the greater FI, which is not overlapped by the curve of the lower FI value, shows just how much advantage the given high near-kin have over the given low near-kin in the probability of producing high racing capacity in the offspring. Thus by examining such a diagram, or the statistical tables on which it is based, we can find out how greatly, in the long run, we must improve the near-blood-kin in order to increase by only a little the probability of a slight but definite increase in the racing capacity of the foal. It is noted that each such cross-section moreover, wherever taken on the same model, incloses, with its base, an area of 1.000, which is the probability of certainty. Each offspring must, of necessity, pos-



"GALLANT FOX" AS A FOAL AND HIS DAM "MARGUERITE"

MANY BREEDERS CONSIDER THE SIRE MORE IMPORTANT THAN THE DAM IN PRODUCING HIGH RACING CAPACITY IN THE FOAL, BUT THE PRESENT INVESTIGATIONS ASSIGN CREDIT TO RACING CAPACITIES AMONG THE NEAR-KIN OF THE DAM AT LEAST EQUAL TO SUCH CREDIT AMONG NEAR-KIN OF THE SIRE.

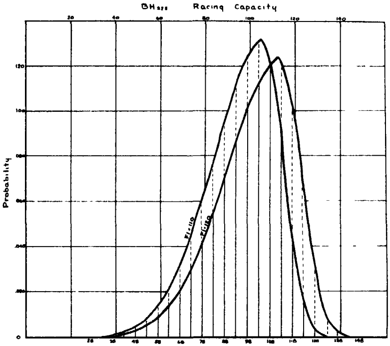


FIG 6 PROBABILITY "OVERLAP" OF OFFSPRING VALUES
BH EXPECTATIONS FROM FI = 110 AND FI = 120.

Overlap for FI = 110 and 120 areas: ΣP = 8221 . . . or ⅘ overlap
Peak P = .1205 at BH = 108 ± 2.5
Limits P = .001 at BH = 38 ± 2.5 and 133 ± 2 5

Non-overlap for FI = 110 area alone : ΣP = .1779 . . . . . . or ⅕ non-overlap
Peak P = .1313 at BH = 104 ± 2.5

Non-overlap for FI = 120 area alone · ΣP = .1779 . . . . or ⅕ non overlap
Peak P = .1230 at BH = 111 ± 2.5

Examples:

1. When BH = 83 ± 2.5
   Overlap. FI = 110–120 P = 0560
   In FI = 110 area alone P = .0222

   ΣP for BH = 83 ± 2.5 = .0782
   Ratio P's. .72 overlap : .28 FI = 110 area alone or about 3.5 : 1

2. When BH = 113 ± 2.5
   Overlap. FI = 110–120 P = .0867
   In FI = 120 area alone P = .0336

   ΣP for BH = 113 ± 2.5 = .1203
   Ratio P's. .72 overlap : .28 FI = 120 area alone or about 3.5 : 1

3. When BH = 133 ± 2.5
   Overlap. FI = 110–120 P = .0005
   In FI = 120 area alone P = .0094

   ΣP = .0099
   Ratio P's. .05 overlap : 00.95 FI = 120 area alone or 1 : 19

sess a racing capacity somewhere between zero and perfection, and the summation of all of its definite capacity-chances must always equal 1 000.

If, in such a diagram, the overlapping were complete, there would be no such thing as the inheritance of racing capacity; we would get the same range in offspring-values from poor stock as from good stock In the mathematical model of any specific formula of heredity, steepness and narrowness in general shape, and an axial trend which gives the *minimum overlapping, indicate* good prediction. If, on the same scales, a model shows much overlapping and a sprawling flatness in shape, it means that the investigator has not succeeded very well in finding a good prediction-basis. But experimental re-stressing of prediction-units can seek a better prediction-basis without destroying the element of truth already found. The present type of operative formula carries procedure for its own criticism and perfection.

Gene-Analysis and Prediction Analysis

If, when we are confronted by a very complex hereditary quality which definitely runs-in-the-family, we use the method here outlined, we can find a mathematical picture of Nature's behavior in transmitting the quality from one generation to another. There is no inconsistency between Mendelian or gene-analysis, on the basis of many interacting factors, and that procedure of genetic analysis which here supplies the specific formula of heredity, by the technique here called "ogive-regression-probability" If with the latter type of analysis the investigator will build the mathematical model for the particular formula, he will be aided substantially

FIG. 6. PROBABILITY OVERLAP

If we take two transverse sections or "very thin slices" from the model shown in Figure 5, and still keep them in their relative positions right-and-left, but push the forward slice backward until it is superimposed on the backward slice, we secure a diagram like Figure 6. The line marked FI = 110 shows probability-distribution by capacity of offspring which come into the world with an FI (Futurity Index, or hereditary promise of a racing capacity) of 110, based on antecedent near-kin racing capacities, while the second bell-shaped curve shows a similar distribution for offspring with a 10-pound higher hereditary promise, namely an FI of 120 The vertical strips within these areas represent ranges of 5 pounds in BH, or racing capacity, of offspring. No matter where we take a cross-section of the model of the formula, the area of the cross-section must always total 1 000—made up of all of its 5-pound probability-strips. If the modal BH class has a low probability, then the cross-section is low and broad—poor prediction; but if the modal class is high, then the cross-section is *narrow and tall—good prediction*

If we look at this Probability Overlap chart we find that the best horses produced from mediocre promise are occasionally much better than the poorest horses produced from superior stock, but, in the long run, the better horses come from the better stock. It is the measure of this "long run" which is here worked out.

It is noticed that with FI of 110, the probability of producing a foal with a racing capacity of 118 ± 2 5 is about 4 times in 100, while the probability of producing such a foal from an FI of 120 is about 10 times in 100. If we increase the racing-capacity expectation to 128, the 110 FI shows a probability of about 4 in 1,000, while the 120 FI shows a probability of about 30 in 1,000. It is this "marginal advantage" for which breeders strive in their efforts to secure superior foals and to improve their breeding stocks.

Man o'War is perhaps the greatest Thoroughbred which America has produced. This country is now producing between 4,000 and 5,000 Thoroughbred horses per year, and if it can produce one Man o'War every twenty years it will be doing splendidly. Man o'War was foaled with a Futurity Index or hereditary promise of 113. He actually developed a racing capacity of nearly 140. What is there in heredity if the promise of 113 will produce a capacity of 140 and why did not a higher promise, which sometimes runs as high as 125, produce the best horse?

It is thus seen that the probability of producing a foal as good as Man o'War from an hereditary promise of 113 is about 1 in 8,000. An FI of 113 is itself quite high in hereditary promise, because only a small portion of all foals produced come into the world with an FI of 113 or greater. This is why, if from the present breeding stocks and by the present methods of mating, America can produce a Man o'War every twenty years, she will be doing well

in the genetic analysis of his problem. For instance, a cross-section of the model in its lower prediction-values (but still, in the present model, substantially above the mean of the breed) will show a tall, steep slope, while another section with a still higher prediction-basis (*i e*, still further above the mean) will show a lower, flatter slope. This indicates that heredity-prediction is better among the lower plus-values of racing capacity, for the strain under consideration, than among the upper plus-values.

Again consider the upper breed-values represented by the blood found in the leading breeding farms for the Thoroughbred horse. Among such superior strains, the present evidence indicates that the Thoroughbred horse is less pure-bred or more variable, in Mendelian terms more heterozygous, for the higher plus- than for the lower plus-values of racing capacity of the antecedent near-kin. As further evidence in using the general formula of heredity as an aid in Mendelian interpretation, we find that, based on the shape of the present mathematical model, the lower plus-values in racing capacity depend upon relatively more recessive phases of the more important constituent genes for this quality than do the higher plus-values. In this, and doubtless in many other ways, the Mendelian interpretation, and the formula of heredity or analysis by ogive-regression-probability, may aid each other. If they are the only two ways of looking at the truth, and each presents a true picture, the two pictures must be consistent.

In the analysis of the more complicated qualities, genetics needs to attack the problem from many directions. It may be interesting, therefore, to compare the uses and limitations of the technique of gene-analysis with analysis by ogive-regression-probability. We find that Mendelian or gene-genetics predicts the nature of the offspring by qualitative classes or categories, determined by one gene or by the additive combination of a few genes. Its principal strength is that it is often able to tie-up its breeding predictions with the underlying chromosome mechanics. Its main weakness is that it can offer no satisfactory genetic analysis or prediction for those more complex traits which are definitely hereditary, and which constitute the main materials with which practical breeders and students of embryology and evolution are constantly working.

Ogive-regression-probability as here outlined presents a general or pattern formula of heredity, the specific application of which also predicts offspring values The basis of such prediction is a measured or quantitative range-of-value for a single complex trait, rather than for a combination of segregable qualitative or unmeasured traits For the "thing-predicted" ogive-regression-probability establishes arbitrarily selected but definitely measured offspring class-ranges It deals with those qualities which result from the developmental interaction of a great many genes Its main virtue is that, in its attack on genetic analysis, it can produce an accurate offspring-prediction for certain very complex measurable structural or functional entities. Its main weakness is that it can not analyze such traits into their constituent genes; it can indicate only their relative number and potencies But for the more complex qualities which definitely run-in-the-family neither has gene-analysis made much headway in specific gene-determination. Each within its own sphere, these two types of genetic analysis are equally accurate in offspring-prediction, while each has its own kind of strength and its own kind of weakness. The type of problem, and the "favorableness of the material," determine which technique will probably prove the more profitable. Doubtless in some cases the two methods working together will be more successful in the discovery of the

truth about a genetical problem than either one by itself.

In keeping with current developments in the physical sciences, probability-mathematics comes in for ever increasing usefulness in the biological sciences also. This is true whether the investigator is making an early reconnoissance and seeking a hint of "how it is," or whether the particular study is well developed and he is seeking to defend the theory and to check it critically against experimental facts

Conclusions

The principal findings of these studies on racing capacity in the Thoroughbred horse are:

1. In order to find the specific formula for the inheritance of the specific quality in a specific group of organisms, two conditions are necessary. First, the investigator must have in hand a reliable yard-stick for measuring quantitatively the particular subject quality; and second, the quality thus measured must show some indication of "running-in-the-family."

2. Racing capacity in the Thoroughbred horse is a definite and measurable functional entity. The existence of long-ago invented yard-sticks for measuring the elements of racing capacity—years for age, pounds for weight-carried, furlongs for distance-run, and seconds for time—made it possible to invent a definite and accurate yard-stick which duly inter-compensates these major factors in relation to speed-attained—other factors, relatively minor, being constant.

3. Nearly every physiological and nervous quality, besides the whole anatomical structure of the individual horse, is called upon for superior racing performance. Consequently the great majority of the individual genes, representing nearly all hereditary resources—in fact the whole organism—is involved in determining the quality of racing capacity.

4. Heredity plays a major rôle in the production of racing capacity, although the influence of care, feeding, training, management and riding are essential environmental factors in the development of ability.

5. The formula for the inheritance of racing capacity in the Thoroughbred horse (Fig 4) is abbreviated as follows:

$$P \text{ sel } BH \pm 2.5 = f(FI, BH).$$

This means that P is the probability that a potential foal, with a given FI or complex of racing capacities among its antecedent direct and collateral near-kin, will, if such foal races, possess a Racing Capacity within the range BH $\pm$ 2.5

This is the Pattern Formula of Heredity, a specific case of which is shown in Fig. 4, and the mathematical model of which specific case is pictured in Fig 5. The fore-and-aft coördinate is the prediction basis, the FI; the right-and-left coördinate, racing capacity, BH, in the offspring by 5-pound ranges; and the up-and-down coördinate is the probability P.

6. With an adequate number of prediction-bases and their corresponding offspring-values in hand, one may apply the pattern formula here developed and thus find an empirical formula by which Nature governs the transmission of the particular quality in the particular group sampled. The present specific formula (Figs. 4 and 5) is for the offspring of the 54 mares produced on Mr. Walter J Salmon's breeding farm, Mereworth, in the course of these laboratory experiments and which offspring raced to maturity during the years 1925–1930.

7. The prediction-index when it contains only a few ancestors, each doubtfully stressed, gives a low prediction-value; but when it comprises a highly representative group of close antecedent blood-kin, each properly stressed, then the prediction-value of the specific formula is high.

—*Photograph by New Zealand Government*

FELLING A GIANT KAURI (*AGATHIS AUSTRALIS*) AT KAINGAROA, NORTH ISLAND, N. Z.

TWELVE CENTURIES OLD AND STILL GROWING STRONG, SOLID TO THE CENTER, DRIPPING WITH SAP, PITCH OOZING OUT OF THE BARK (ABOVE THE AX), YET THIS MONARCH OF THE FOREST STARTED IN ROMAN TIMES AND HAS SHED A RAINFALL THAT WOULD HAVE COVERED THE EARTH TO A DEPTH OF 10,000 FEET. THE GIRTH IS 66 FEET AND UNIFORM TO THE FIRST LIMB—40 FEET UP, THEREFORE 130,000 FEET OF PINE WITHOUT A KNOT. THE ANNUAL SCALING OF THE BARK ACCOUNTS FOR ITS THINNESS—THE WOOD ITSELF BEING 21 FEET THROUGH. IN SEQUOIA THE BARK IS OVER A FOOT THICK, IN AGATHIS LESS THAN HALF AN INCH, JUST THE YEAR'S GROWTH, TRULY AN OUTSIDE GROWTH, AN EXOGENOUS STEM.

THE NEW ZEALAND FOREST

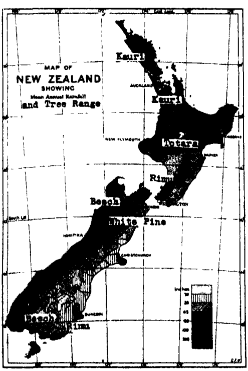
By V. W. JACKSON

PROFESSOR OF BIOLOGY, UNIVERSITY OF MANITOBA; FORMERLY DIRECTOR OF NATURE STUDY IN NEW ZEALAND SCHOOLS

OF the eight hundred trees, shrubs and vines of New Zealand, six hundred are endemic—not found anywhere else. Why this museum of woody oddities in two islands about the size of the Atlantic states from Georgia to Maine and in the same latitude, 34°–48° south? Isolation is sufficient explanation Not only is New Zealand separated from the nearest land by 1,300 miles (twice the isolation of Bermuda), but the surrounding ocean is 3,000 fathoms deep, which would indicate long isolation—yes, since early Tertiary times, when the Atlantic states were beneath the ocean and palms grew in Greenland

No wonder, then, the trees of New Zealand are so peculiar—pines with berries, ferns like trees, broad-leaved evergreens, trees which change their leaves, trees without leaves, trees with daisy flowers, woods that sink in water, woods lighter than cork, Fuchsia-trees, cabbage-trees, net-veined monocots, straight-veined dicots, coniferous dicots; yes, three out of every four you have never seen before, nor anything like them. Of the twenty pines only one has the semblance of a cone and that is as round as an egg Nineteen pines have gay-colored berries to attract the birds. The berries of the white pine are red at one end and blue at the other, and hence called "soldier berries" Fancy, Verbena trees in flower the year around, but with wood so hard and heavy it sinks, and violet trees thirty feet high, male and female —the Mahoe of the Maori. Stranger still are the daisy trees, the dominant forest trees of Stewart Island, yellow daisy flowers, seeds with thistle-down, twenty different kinds, found only in New Zealand. In fact, of the 1,700 species of flowering plants, 79 per cent. are endemic and half of all the plants are woody, so that the forest flora is the major portion and the keynote to New Zealand scenery

The New Zealand forest is a true subtropical rain forest, with trees and lianes struggling for a mastery; 182 species of trees, 316 shrubs, 241 semi-woody plants, 51 vines, 12 tree ferns; over 800 woody plants, a tangle of tropical luxuriance, a typical liane: which, like the blessed word "Mesopotamia," brings joy to the rapturous and thrill to the novice—this "rampant wrestle for ascendancy." Clematis and passion-vine, supple-jack and kie entwine the giants of the forest



—*Photograph by J Martin, Auckland*

THE GIANT KAURI, THE ELEPHANT OF TREES, STANDS IN A CLASS BY ITSELF

A GREEN DORIC COLUMN OFTEN 20 FEET IN DIAMETER AND 60 FEET BEFORE A LIMB, 185,000 FEET OF BEST PINE LUMBER WITHOUT A KNOT THIS IS THE SOURCE OF KAURI GUM, USED IN FINEST VARNISHES. THE TOP OF THIS GIANT BECOMES THE LODGMENT OF MANY EPIPHYTES, MOSTLY ORCHIDS AND LILIES. THE LONG VINE SEEN HANGING ALONG THE TRUNK HAS GROWN DOWN FROM BIRD-CARRIED SEED OF THIS HARD WOOD RATA AND EVENTUALLY BECOMES ROOTED TO THE EARTH (WHERE THE MAN IS STANDING) AND SOON BECOMES AN INDEPENDENT TREE, STRANGLING LESS STURDY HOSTS, AND BECOMING THE HARDEST AND HEAVIEST OF WOODS.

in their struggle for light and make an impenetrable tangle The kie-kie is a lily vine, hanging from supporting limbs like a cascade of foliage, and supple-jack is another lily vine, hanging like ropes from the topmost branches and often used as ropes. The Clematis vines, of which there are nine kinds, are all endemic and all dioecious—two kinds, staminate and pistillate; in fact, 46 per cent. of New Zealand flora are unisexual, evidence of primitive types and also of separation for cross fertilization *Clematis indivisa* forms huge clusters of large white flowers high up in the trees, with the passion-flower hanging lower. To add to the tangle, blackberry bramble was introduced and has so thrived as to become known as bush-lawyer.

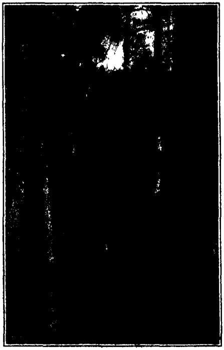
In the north island rain forest stalwart pines predominate, with a strange exotic mixture of subtropical palms, cabbage-trees (*Dracaena*) and tree ferns,

—*Photograph by New Zealand Government*

O WOODMAN, SPARE THAT KAURI—THERE ARE FEW LEFT AND NONE OTHERS LIKE THEM

NO OTHER TREE HAS SUCH A MASSIVE, UNIFORM, COLUMNAR TRUNK—WITHOUT LIMBS, WITHOUT A KNOT, THE FINEST LUMBER, THE FAVORITE OF THE CABINETMAKER. NO WONDER IT WAS MUCH SOUGHT AFTER AND NEARLY DISAPPEARED. ONLY ISOLATION IN INACCESSIBLE MOUNTAINS SAVED THE KAURI WHICH ARE LEFT. THE PALMS, TREE FERNS AND GRASS TREES IN THE BACKGROUND INDICATE THE SUBTROPICAL RAIN FOREST.

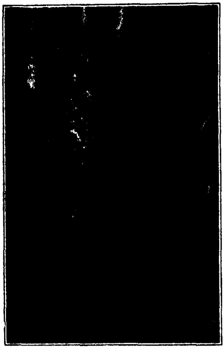
eight different kinds, in close association with broad-leaved trees with thick, glossy leaves. Monarch of all is the kauri (*Agathis australis*) the most majestic of the pines—great doric columns of stone-gray bark, giving a hazy sanctity to the silent woods. These are the trees primeval—the rearguard of the past, the prophet of the future, fast disappearing before the onslaught of saw and fire; for the kauri is a pine of finest quality, often 16 to 20 feet in diameter, and 80 feet without a knot It is the



—*Photograph by J Martin, Auckland*

THE KAURI FOREST IS SACRED WITH ANTIQUITIES; GRASS-TREES IN FOREGROUND, CLIMBING FERN ON KAURI TRUNK

TMESIPTERIS, A STRANGE "MISSING LINK" BETWEEN THE SPORE AND SEED PLANTS, EPIPHYTIC UPON THE TRUNKS OF TREE FERNS. THE WIRY VINE TIGHTLY APPRESSED AND ASCENDING THE KAURI TRUNK ON THE RIGHT IS A CLIMBING FERN (*Lygodium*) ENDEMIC TO NEW ZEALAND. THE PALM-LIKE CLUSTERS ON THE LEFT ARE NOT THE LEAVES OF A MONOCOT BUT OF A HARDWOOD DICOT —THE ONLY ONE WITH STRAIGHT-VEINED LEAVES.



—*Photograph by New Zealand Government*

TROUNSON'S KAURI PARK, NORTH AUCKLAND, N Z.; ONE OF SEVERAL STATE FORESTS

LIKE THE REDWOOD, THE KAURI HAS A VERY LIMITED RANGE, ONLY THE NORTHERN TIP OF THE NORTH ISLAND, LAT. 33° S. TO 38°. ONLY TOO LATE NATIONAL KAURI PARKS HAVE BEEN SET ASIDE TO PROTECT THIS FAMOUS TREE FROM EXTINCTION. THE STATES FORESTS ACT OF 1922 PROVIDES £1,000,000 FOR PROTECTION AND AFFORESTATION AND THE KAURI STAND IS NOW A STATE MONOPOLY, A NECESSARY PROTECTION AGAINST GUM-POACHING, FOR KAURI GUM IS A VALUABLE BY-PRODUCT.

"Big Tree" of New Zealand and now must be preserved for posterity as the only pine south of the "Russel Line" with cones and broad leaves.

The other 19 pines have fleshy berries or colored, aril growth around the bony seed like the yew and are therefore Taxaceae and not Pinaceae, certainly not Coniferae—not cone-bearers. The four most common pines, totara, miro, matai and white pine, belong to the genus *Podocarpus*, which means a berry with a

base: the white pine or "soldier berry" being red below and blue at the top, like the French gendarme. The Maoris are fond of these berries The average tree is 120 feet and the wood is used in making butter boxes and paper. The two black pines, miro and matai, have fruits like a plum; the red miro being the favorite fruit of the native pigeon, and the black plum of the matai is partly hidden among flat leaves on spreading branches like a dicot. you would never guess it a pine until you tasted the pitchy leaves or berries. The totara was the favorite of the Maori, for out of it he carved his war canoes, sometimes 70 feet in length and enduring the centuries, for it is one timber which resists "Teredo," the ship worm

The hardwoods are not less remarkable Three of them sink in water and can therefore not be floated to the mill. Even my Maori war clubs, cracked with time and desiccation, sink like lead in water, a real bludgeon these, of black maire (Olea—olive) and rata or ironwood (*Metrosideros*, which means hard as iron) Black maire weighs 72.3 pounds per cubic foot, and growing beside it may be whau, a New Zealand basswood, which weighs only 11.7, the whole log lighter than cork, and used as

—*Photograph by J. Martin, Auckland*

A STRANGE MEDLEY OF MONOCOTS AND DICOTS; THERE ARE 185 SPECIES OF COASTAL FLORA

GROWING UP THROUGH THE NEW ZEALAND FLAX (*Phormium tenax*) IS THE CABBAGE TREE (*Cordyline australis*) LIKE A HOTHOUSE DRACAENA ON A POLE. THE WAVY-LEAVED RANGIORA ON THE RIGHT HAS FLOWERS LIKE AN ASTER, AS HAVE MOST OF THE TREES ON STEWART ISLAND OF THE GENUS SENECIO—DAISY TREES, IN FACT. THE CROOKED BRANCHES OF THE POHUTUKAWA OR CHRISTMAS TREE WITH ITS SCARLET FLOWERS REACHES FAR OUT OVER THE WATER IN SEARCH OF LIGHT.

—*Photograph by J. Martin, Auckland*

PALM, PINE AND FERN HOLDING UP A TANGLE OF VINE; A TYPICAL LIANE RAIN FOREST

KIE KIE, SUPPLE-JACK AND CLEMATIS ALL ONE ENSEMBLE KNOWN AS RAIN FOREST OR LIANE. THE PINES HAVE BERRIES INSTEAD OF CONES; THE FERNS HAVE TRUNKS LIKE TREES; THE VINES HAVE SHOWY FLOWERS; THE EPIPHYTES ARE WHITE LILIES OR DENDROBIUM ORCHIDS; A KAURI PINE IN MID-BACKGROUND AND A WHITE PINE BEHIND THE NIKAU PALM.

floats in netting whales—one wood over six times as heavy as the other Interspersed with these hard woods, with thick, glossy, dark-green leaves and prune-like fruits, will be nikau palms and cabbage trees (*Dracaena*), a medley of the tropical with the antipodal, a vegetational vaudeville.

The evergreen broad-leaved trees and freedom from frost means an evergreen forest relieved only by flowering trees, for there is neither room nor light for wild flowers and most of the tree flowers are greenish, but at Christmas time the Christmas tree, pohutukawa (*Metrosideros tomentosa*), bursts scarlet red with bloom—the countryside becoming red over night—a red Christmas instead of a white one.

The southern rain-forest is a beech-forest, an almost pure community of one or more species of beech (*Nothofagus*) in a bed of fern Even the beech is antipodal, more like birch than beech and called red and black birch by the lumberman. However, they have burry beech-nuts and outstretched horizontal branches—*Nothofagus* if not *Fagus*. But the tree ferns are much the same and the keynote of the New Zealand forest—a continuity and a tropical character, which makes the New Zealand forest one liane or tangle of endemic trees, ferns and vines.

It is most surprising to find these tropic-like tree ferns as far south as the Auckland Islands, Lat. 50° S.—the latitude of Winnipeg and the Aleutian Islands. Humidity and the tempering influences of a vast surrounding ocean make this possible.

Although isolation tends to fixity of species and 79 per cent. of the flora is endemic, yet there is a remarkable and unexpected hybridization—353 species-hybrids and 101 generic-hybrids, mostly among trees and shrubs. Of the sixty coastal trees and shrubs 10 per cent. of them have hybridized—one tree-shrub hybrid. Of the 222 lowland trees and shrubs there are seven tree-hybrids, 25 shrub hybrids and two between trees and shrubs. Of the 125 mountain trees and shrubs there are 47 hybrids, and among the 45 lianes there are 10 hybrids and 9 epiphytic-hybrids, in all 87 hybrid groups among the 410 woody plants, and 107 among the 845 herbaceous. Such hybridity or heteroblasty makes systematic flora a very difficult and puzzling problem. It has challenged the botanists of the world for half a century Hooker, Travers, Engler, Colenso, Kirk, Petrie and Cheeseman were puzzling over these things in floras of fifty years ago, and more recently Dr. Cockayne and Dr. H. H. Allan have studied this hybridization critically, and find well-established varietal groups, notably Veronicas, Pimeleas, Pittosporums, daisy trees, cabbage-trees, spiderwoods and many others And all this hybridity with a scarcity of insects and birds! True, most of the flowers are white and these attract moths at night, and the honey flowers of the trees attract the birds, but such surprising hybridization must be due to the equally surprising fact that nearly half the flora is unisexual, that is, the flowers are of two kinds, staminate and pistillate, male and female, on the same or on different trees, and therefore must be crossed, if fertilized at all. It has been estimated that 54 per cent. are thus cross-fertilized, and the possible isolation of such incipient species prevents the swamping effect of crossing, as on continental areas. So we have this unique flora of New Zealand—79 per cent. endemic, 46 per cent. unisexual, monoecious or dioecious, nearly half the flora woody—trees, shrubs and vines, hence a forest of oddities, antipodals, daisy trees, grass trees, fern trees, pines without cones, trees without leaves (*Phyllocladus* and *Carmichelia*), trees with changing leaves (lancewood, Discaria, ribbon wood), the

—*Photograph by J Martin, Auckland*

PERHAPS THE MOST SOUTHERN TREE–FERN, LAT. 45° S.

Within sight of the Tasman Glacier, Southern Alps, N. Z., Lat. 45° S. (latitude of Montreal), this black tree-fern (*Cyathea medullaris*) holds aloft its delicate fronds, 20 feet long. Slightly smaller tree-ferns (*Hemitelia Smithii*) grow on Stewart Island, Lat. 47°, and even on Auckland Island, 50° S. (latitude of Winnipeg and Aleutian Islands).

—*Photograph by New Zealand Government*

THE MILFORD TRACK, THROUGH THE SOUTHERN BEECH-FOREST, SOUTH ISLAND, N. Z.

ONE OF THE FINEST WALKS IN THE WORLD, THROUGH FERNS AND BEECH, MILES AND MILES, AND THERE IS NO OTHER WAY THAN WALK THROUGH THIS MOUNTAINOUS REGION TO MILFORD SOUND ON THE WEST COAST. ALTHOUGH IN A SEEMING TROPICAL FERNERY THERE IS A CHILL IN THE AIR FROM THE NEARBY GLACIERS AND THE FIRST OPEN VIEW WILL LIKELY REVEAL THE FRANZ JOSEPH GLACIER ON MT. COOK, 12,349 FEET ALTITUDE—TREE FERNS AND GLACIERS, A FLORAL PARADOX AS WELL AS A FLORAL PARADISE.

thick, glossy, tropical leaves, spiny, xerophytic leaves (where there is 200 inches of rainfall), hardwoods heavy as stone or light as cork—a forest laboratory, trying out everything, keeping that which has stood the test of time, some since Devonian time.

CLASSIFICATION OF NEW ZEALAND WOOD FLORA
(Referred to in text)

Tree-ferns *Cyatheaceae*
Cyathea dealbata, ponga, silver t f
Cyathea medullaris; Koran; black t f, 50′
Dicksonia squarrosa; weki; 20′
Dicksonia fibrosa; weki-ponga, 20′

Pine, Conifer. *Pinaceae*, *Araucarieae*
Agathis australis; kauri
Yews, Taxaceae, Podocarpeae
Podocarpus totara; totara (pine)
Podocarpus ferrugineus; miro, black-pine
Podocarpus spicatus; matai; black-pine
Podocarpus dacrydioides, kahikatea; white p
Dacrydium cupressinum, rimu, red-p
Phyllocladus trichomanoides; celery leaved p

Screw Pine Family · kie-kie vine
Palmaceae; nikau palm, only palm
Liliaceae, cabbage-tree (Cordyline) Dracaena
Supple-jack vine (*Rhipogonum scandens*)
New Zealand flax (*Phormium tenax*)

Beech Family: *Fagaceae*
Red birch; *Nothofagus Menziesii*
Black birch; *Nothofagus fuscus*
White birch; *Nothofagus solandri*

Nettle Family: *Urticaceae*
Nettle-tree; *Paratrophis microphyllus*
Nettle-bush; *Urtica ferox*

Mistletoes: 3 parasitic Loranthus, Viscum, Tupeia

Proteaceae; Australasian only
Rewa-rewa; *Knightia excelsa*, 100′

Sandalwood; *Santalum Cunninghamii*
Polygonaceae; Climbing shrubs (Muhlenbeckia)
Ranunculaceae; Climbing *Clematis indivisa*
Magnoliaceae. pepper tree; *Drimys axillaris*
Lauraceae; tawa and tarairi (*Beilschmiedia*)
Saxifragaceae; seven trees—Weinmannia Carpodetus, Ixerba and Ackama
Pittosporaceae. Matipo; Australasian Pittosporum—17 trees and shrubs
Leguminosae; mostly trees and shrubs, Sophora
Violaceae, Violet-tree, Melicytus, Mahoe
Mahogany: *Dysoxylum spectabile;* kohe kohe
Maple family. *Dodonaea* (ake), Alectryon (Titoke)
Passifloriae; Passion flower vine
Karaka: *Corynocarpus laevigata*, "laurel"

Basswood, Lime or Linden Family
Whau; *Entelea arborescens*, lighter than cork
Hinau; *Eleocarpus dentatus*, softwood

Ribbon woods or Mallows
Lacebark: *Hoheria populnea*
Ribbon wood; *Plagianthus betulinus*

Daphne family a dozen shrubs (*Pimelea*)
Myrtle family: tea-trees and ratas
Leptospermum—3 teatrees, Manuka
Metrosideros, 9 large trees and 2 vines
Myrtus—4 shrubs
Eugenia Maire, hardest of woods
Fuchsia tree, *Fuchsia excorticata*
Dogwoods, Broadleaf Griselina
Araliads, Lancewoods—13 species Nothopanax 7, Pseudopanax 6
Wintergreen tree; *Gaultheria antipoda*
Grass-trees; *Dracophyllum*—18 species
Olive Family Olea, maire—heaviest of woods
Verbenaceae 4 hardwood trees, Vitex Avicennia (Mangrove) and Myoporum
Veronica, 84 species, mostly shrubs
Coprosma; 40 species, mostly shrubs
Compositae; Daisy family, mostly trees and shrubs in N. Z.
Olearia—35 trees and shrubs, all endemic
Senecio—20 trees and shrubs, all endemic.

THE ENTOMOLOGICAL SOCIETY OF LONDON

By Professor T. D. A. COCKERELL
UNIVERSITY OF COLORADO

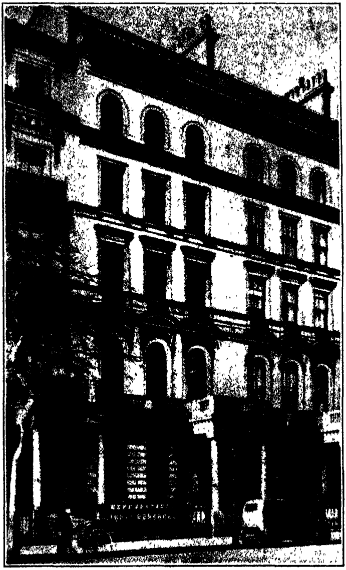
THE first of all entomological societies appears to have been founded in London in the forties of the eighteenth century Practically nothing is known about it, except that the members used to meet at the Swan Tavern, 'Change Alley, and that on March 25, 1748, a great fire occurred, which destroyed both library and collections A meeting was in progress when this happened, and the members had difficulty in escaping with their lives This disaster seems to have put an end to the society. In 1762 a second Aurelian Society was founded, and for a time seemed to flourish But before the end of the decade it had come to grief, and on February 28, 1768, the English entomologist, Dru Drury, wrote to Pallas in Russia: "I sincerely lament with you ye fall of ye Aurelian Society, there wanted but two or three good members to have made it become respectable, but Da Costa's temper and principle was sufficient to overturn a kingdom "

Another society was founded in 1780 and lasted two years Then in 1801 the name Aurelian Society was revived for a new organization, which dissolved in 1806 From this time on various efforts were made, and the long record of failures seemed to suggest that a society devoted to entomology alone could not have lasting success. The Linnean Society, covering the whole field of biology, was a flourishing institution, and many felt averse to dividing up the field, and creating special societies concerned with portions of it.

All this was long before the rise of economic entomology, and those who studied insects were amateurs, interested in the beauties and wonders of nature They were not "mere collectors" by any means, but also took a keen interest in observing the habits of their favorites, as is well shown by the letters of Dru Drury and the writings of William Kirby. In spite of so many difficulties and discouragements, they still felt that they must come together to discuss their common interests and that the field of entomology was large enough to justify a special society Indeed it may be said that the variously abortive efforts of nearly a century past had but paved the way for the success which was to come

So it came about that on May 3, 1833, a group of men met at the British Museum, and decided to establish the Entomological Society of London, which has steadily developed during the past century, and recently celebrated the hundredth year of its existence. In commemoration of this event the society has just published "The History of the Entomological Society of London, 1833–1933," by Dr. S A Neave, assisted by Mr. F. J. Griffin, with an introduction by Professor E. B Poulton and a financial chapter by A. F. Hemming. It is from this excellent account that I derive most of my information The society started well, with 107 members in its first year, including Charles Darwin and others already eminent or destined to become so. The venerable William Kirby, rector of Barham, at that time the most distinguished British entomologist, was elected honorary life president. Probably the most influential and in the long run the most distinguished as an

entomologist of all the original members was John Obadiah Westwood, for long years professor at Oxford He died as recently as 1893, and among my most treasured memories is that of seeing him preside at one of the meetings, when he read a paper on a new kind of plant-louse found on breadfruit in Ceylon Westwood it was who published the classical "Introduction to the Modern Classification of Insects," which did indeed place the whole subject on a new basis, and marked the beginning of a new era in entomological science Before the general recognition of the importance of economic entomology, he concerned himself with injurious insects as such, and published many important



41 QUEEN'S GATE, THE HOME OF THE SOCIETY SINCE 1921

REVEREND WILLIAM KIRBY, F.R.S.
HONORARY LIFE PRESIDENT, 1833–1850

papers in the *Gardener's Chronicle.* He studied all groups of insects, and his enthusiasm never flagged, so that it was said of him that in spirit he never grew old. His artistic powers were great, and led him not only to skilfully illustrate innumerable insects, but also to become a leading authority on medieval manuscripts.

When one looks at the list of men who established the Entomological Society in 1833, the number of first-class men is astonishing. Some of them are chiefly known to-day for their activities in non-entomological fields, such, for instance, as Charles Darwin, Sir J. D. Hooker and W. Yarrell. But I can count about fifteen outstanding entomologists, whose work will never be forgotten. These alone would have given luster to any organization they might have chosen to form.

For the first three decades the membership remained between 150 and 160, but then it began to increase, the subsequent decades (beginning with 1863) showing 194, 223, 289, 404, 522, 622 and 685. This steady progress did not mean unclouded prosperity. The finances were often the occasion of serious anxiety, but large and frequent gifts from certain of the members tided over difficult times, and especially made possible the publication of important illustrated papers.

JOHN OBADIAH WESTWOOD

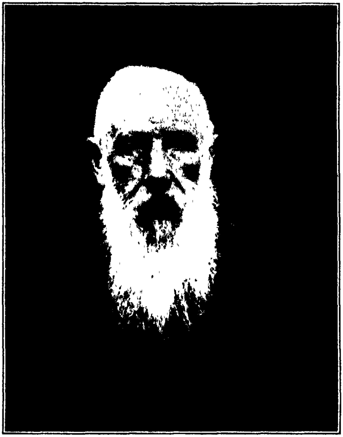
Honorary Secretary, 1834–1847; President, 1851–1852, 1872–1873, 1876–1877, Honorary Life President, 1883–1893

As recently as 1874 it was actually proposed to merge the Entomological Society with the Linnean, and such an arrangement was very nearly made. In the early days of the society, a collection of insects was formed, and this soon came to be of considerable importance. In 1835 the Reverend Wm. Kirby presented the whole of his collections, including the types of bees described in his Monographia Apum Angliae, the basic work for the knowledge of British bees. In 1841 Darwin presented a collection of insects obtained on the voyage of the *Beagle*, "and it appears that on his return from his famous voyage, Darwin was much exercised in his mind as to the disposal of his collections. For some reason he was not anxious to present them to the National Collection at the British Museum, and portions of them were presented to this Society, and, as may be seen from the Centenary History of the Zoological Society of London, others were handed over to that body. As is well known, however, the most valuable portions of both these collections eventually reached the British Museum." To this I can add that I found a couple of bees (one of them still representing a new species) in the Hope Museum at Oxford, collected by Darwin in

Australia and Tasmania It is unfortunate that the history of many of the specimens of insects collected in the early days, and made the types of newly described species, is now difficult or impossible to trace At first it was not customary to put locality labels or other data on the pins, and thus it happened that after Dru Drury's collection, with its many types, was sold, no one could say what specimens belonged to it. Very probably some or many of them are still extant, but there is no way to prove it At the British Museum, it was the custom to put a little label on the pin, showing the year the specimen was received, and the number given to the accession in the accession-book. Thus 50 10 would mean accession number 10, of the year 1850. When these insects were described as new, it was not usual to cite these numbers, but any one who would now go to the museum, and ascertain the numbers on the innumerable types, and look them up in the accession-books, would undoubtedly discover much of interest for the history of entomology. Often, of course, the record merely gives the name of the donor, but frequently the collector or the locality can be ascertained

As might be supposed, the collection of the Entomological Society eventually reached such a size that it was impossible to take care of it. Adequate room could not be found, and the problem of keeping it properly arranged proved insuperable. In 1858 the exotic insects, except the types of new species, were sold by auction, and in 1863 the society disposed of the last of its collections, the types going to the British Museum. In the thirty years since the foundation of the society, the British Museum had increased its facilities and its staff, and it was to the advantage of all concerned that it should become the custodian of these precious materials.

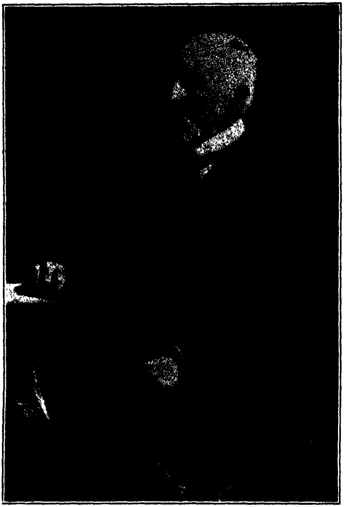
The library, on the other hand, had a very different history. As it grew in size and importance the problem of housing it and making it available became acute The story of how the difficulties were overcome is a long one, but to-day it is estimated that the society possesses about 12,000 volumes and 30,000 separates, much used by the members The question might be raised, why the society should maintain this great library, when that of the British Museum (Natural History) is available just around the corner But the library of the society can be loaned to members, and is increasingly used in this way. An evil resulting from the growth of modern science is that the student, unless he lives near or is connected with some great institution, or is unusually wealthy, can not obtain the literature for serious original researches Indeed, even large universities do not possess all the necessary literature, except in restricted fields which have been especially cultivated by members of the faculty. The consequence is that students have to depend for the determination of specimens and various kinds of advice on the staffs of large museums, service which can only be rendered at the cost of time and effort which would better be directed to work of more lasting value. Even when museums or universities are willing to do this work of determination, the results are often unreliable Every large collection grows by accessions from many sources, and it is utterly impossible for the curators to check up the determinations of the species as they come in Also, it is very difficult to match species correctly, if one is not familiar with the special specific characters. It is accordingly necessary for the sound progress of entomology that there should be many workers specializing in particular groups, exchanging specimens and opinions, and becoming familiar with all the details of their subjects. Such workers, it is obvious, are likely to be



DAVID SHARP

more numerous and more efficient if they can gain access to the most necessary books. One of the greatest possible services to American science would be the establishment of a great loan library, especially of authors' separates, which could be sent out to students under properly safeguarded conditions. The need is partly met by inter-library loans, which are exceedingly helpful, but in the nature of things can not be really adequate.

From the beginning, it was one of the chief concerns of the society to publish its Transactions. There was at first considerable opposition, partly on account of expense and partly because it was feared that there would be serious competition with the *Entomological Magazine*, which had been founded in 1832. Such objections were not allowed to prevail, and it was soon recognized that publication was one of the chief functions of the society. In 1931, to meet the difficulty of publishing short taxonomic papers, the society established the monthly journal *Stylops,* and it is to be noted that the ancient objection, concerning the fear of competition with existing journals, was voiced once more in certain quarters, but with no more effect than before. As a matter of fact publication facilities are still extremely inadequate, and workers are discouraged from attempting comprehensive monographs or long papers.



F. D. GODMAN

In the early fifties, it was proposed to publish a series of volumes under the title *Insecta Britannica*. Volumes on the Diptera (flies) and smaller moths actually appeared, but the scheme was never completed There were various reasons for this, including disputes as to the arrangement and contents of the volumes. To-day it would be recognized that in order to adequately deal with the British fauna, it is necessary to study that of the whole Palaearctic Region, and preferably also that of North America. To begin with the British insects alone is to begin at the wrong end, though it is useful eventually to publish special accounts of the British fauna, to serve the needs of collectors who do not study exotic species. In the early days, when material from abroad was not so generally available or easily obtained, it was a kind of necessity to mainly confine the work to the local species; but the evils resulting from this practise are evident when one contemplates the immense and complicated synonymy of European insects.

In 1867 the Neuropterist, McLachlan,

proposed that a Catalogue of British Insects should be compiled and published by the society. Some parts of this appeared, but the project was never completed. A serious obstacle was the disagreement concerning the nomenclature to be used, there being two opposing groups within the society. An up-to-date Catalogue of British Insects would to-day be of very great value, and also would be easier to produce, as there are so many more monographic or revisional works on which it could be based.

When we consider all the useful activities of the society, costing the members or fellows large sums of money, it is easy to understand why the Commissioners of Inland Revenue declared the society a "charitable body within the meaning of the Act," and exempted it from liability to income tax. It would be difficult or impossible to correctly estimate the value of the Transactions and Proceedings of the society, published during the last hundred years, but at the very least it can be said that they were the means of preserving and making available the work of numerous capable entomologists, who could not otherwise have recorded their observations. Hardly any of this work could have been made commercially profitable, and without the organized support of such a society the development of the science would have been greatly hindered. When we speak of the benefac-

H. W. BATES

tors of science, wealthy men who have contributed large sums for various purposes, it is appropriate to remember those other benefactors who have employed their available time without financial aid, in working out scientific problems and arranging the materials available, and who have also, in their organized or corporate capacity, furnished great sums of money in aid of scientific progress. These are the people who have really borne the burden of the day.

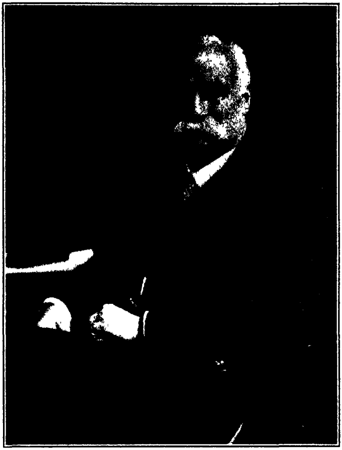
The latest development, more recent than the publication of the history we are reviewing, is the change of the name "by the King's command" to that of the Royal Entomological Society of London This sounds cumbersome, and rather lacking in any real significance, but it is one of the various steps which have been taken to give the society official recognition. In Australia, a very democratic dominion, one is struck by the number of "Royal" societies I attended a meeting of entomologists in Brisbane, and we all put on dress clothes, while the chair was taken by the Governor, who represents the Crown All these frills are not exactly part of science, but if we are sometimes inclined to ridicule them, we are not without regret that our own governors and masters, whom we have elected, have so little appreciation of scientific work. I have a vivid recollection of the semicentennial anniversary of our National Academy of Sciences, held in Washington in 1913. There were memorable addresses by eminent men; the last speech in America by James Bryce, the recollections of the venerable and beloved Weir Mitchell, and others. But the powers that were appeared in the form of Vice-President Marshall, who took the occasion to scold the assembly on account of the unreliable and sometimes dishonest "experts" who appeared in the law courts. The next morning I hastened to get a paper, and saw in great headlines, "Marshall says scientific men can be bought for fifty dollars" (I think those were the exact words), while the really important part of the program was very poorly reported.

Since the success of the society has been so largely dependent on its more eminent members, portraits are given of some of these The secretary of the society, Dr Neave, has kindly supplied me with copies of the plates used in the history, and in addition, has loaned several pictures belonging to the society From all these, the following are selected as the most interesting

William Kirby, 1759–1850. Sometimes called the "Father of British Entomology," co-author with Spence of the famous "Introduction to Entomology," rich in information concerning the natural history of insects, and the first to make a special study of wild bees. The *Stylops kirbii*, a curious parasitic insect named after Kirby, is the emblem of the society, and suggested the name of the recently established journal.

John Obadiah Westwood, 1805–1893. All-round entomologist, professor at Oxford, occupying the chair founded by his friend, the Reverend F. W. Hope. He occupied a unique and most influential place in the history of entomology, but although he lived more than thirty years after the publication of the "Origin of Species," he never became reconciled to Darwin's views.

Henry Walter Bates, 1825–1892. Bates and Wallace made their famous journey to the Amazons in 1848, and the narrative of Bates, setting forth his observations in tropical South America, is now universally regarded as a classic. His name is closely connected with theories of "mimicry" and warning coloration. In his later years he specialized in Coleoptera and described many new beetles. The picture is made from a



EDWARD BAGNALL POULTON, D.Sc., M.A., F.R.S.
President, 1903–1904, 1925–1926, 1933–

photograph of Bates, which an artist has fancifully surrounded with objects supposed to be characteristic of the Amazon, producing a very comical effect

David Sharp, 1840–1922. A most remarkable man, curator of the University Museum of Zoology at Cambridge, and a great authority of Coleoptera. He wrote the two volumes on insects of the "Cambridge Natural History" (1899), perhaps the best general account of the subject ever produced, showing a prodigious knowledge both of the insects and the literature. He prepared a much larger work on the same lines, but most unfortunately, was never able to publish it He was intimately connected with the *Zoological Record*, first as editor of the Insecta part, and afterward of the entire volume. He had a great deal to do with the *Fauna Hawaiiensis*, giving an account of all the animals known from the Hawaiian Islands. With all this, he was a most interesting personality, and many workers still living were inspired by him

Frederick Du Cane Godman, 1834–1919. The names of Godman, Osbert Salvin and G. C. Champion will always be remembered in connection with the great "Biologia Centrali-americana," an attempt to discuss the biology of Mexico

and Central America in minute detail, and list or describe all the animals and plants. The scheme was entirely financed by Godman and Salvin. The types of new insects, which were very numerous, are all to be found in the British Museum. The project was not entirely completed; for example, the bees were never described Naturally, the fauna of such a great and fertile region could not be completely elucidated, and to-day it is probable that the species added to the Biologia lists are as numerous as those there listed, at least in some groups. A serious objection to this splendid work is its great cost Had it been published in a less expensive style, such as that of the "Fauna of British India," it would have been more useful

Edward Bagnall Poulton, president of the society at the present time, for many years Hope professor of entomology at Oxford, a position which he has lately relinquished to his friend and disciple, G. D. H. Carpenter. Poulton is primarily interested in the biology of insects, and especially so-called mimicry and protective resemblance, concerning which he has published many interesting new facts. A man of immense energy and enthusiasm, he is not only the life of the meetings, but has inspired and guided many correspondents, especially in tropical countries, who have been led to make all sorts of discoveries, and have been able to get them properly recorded and the species identified with Poulton's aid

A POSSIBLE INTERPRETATION OF THE QUANTUM

By Dr. W. P. MONTAGUE
PROFESSOR OF PHILOSOPHY, BARNARD COLLEGE, COLUMBIA UNIVERSITY

INTRODUCTION

THE three aspects of the quantum phenomena which seem to be the most puzzling and most challenging to the imagination are:

I. The revolutionary conception of radiant energy as consisting of definite multiples of a definite unit, Planck's mysterious constant *h*.

II. The reconciliation of the new conception of radiation as discrete and quasi-corpuscular with the older but equally valid conception of radiation as continuous and undulatory.

III. The structure of the atoms and the manner in which a discretely continuous radiation is emitted from and absorbed by them.

I shall consider these three problems in turn and suggest a possible solution for each of them.

I. THE NATURE OF H AND THE REASON FOR THE EQUATION E = H · NU

The intensity of light, like the intensity of sound and gravitation, varies inversely as the square of its distance from the source. Yet despite this undenied fact the energy of a light-wave (as measured by the energy given to an electron that is expelled from a photoelectric screen by the impact of the wave) depends not at all upon the distance of the light-wave from its source but solely upon the length of the wave. The shorter the waves the higher the frequency or number passing a given point in a second. And the energy of light of a given wave-length is measured by the product of its frequency symbolized by *nu* and a certain very small fixed quantity. This small quantity is itself the product of energy and time and as such is called "Action." It is the famous constant discovered by Professor Planck. Its value is $6.55 \cdot 10^{-27}$ erg-seconds and its symbol is *h*. Hence the measure of the energy, e, of a light-wave or more properly of an electromagnetic wave of any length is expressed in the equation e = h · nu. The baffling situation thus presented and formulated raises two fundamental and hitherto unanswered questions.

(1) Why does the energy of radiation increase with its frequency?

(2) What is the real nature of Planck's constant *h*?

I trust that the reader will bear with me if I first state my answer to these questions in the form of a little fable or allegory. Allegories do not usually help in matters of physics, but I think that this one will. It will help me at any rate to make plain the conception which I wish to submit for consideration.

When I was very young there lived in my town a prosperous and happy but most peculiar family. There was Henry, the father, who was thin and incredibly tall, a regular giant, in fact. He had two children, Harry, who was a sturdy half-grown boy, and Harriet, a tiny girl but amazingly active for her size and age. There was also a nephew, Cousin Hal as the children called him, a tall slender youth who visited the family almost every Sunday. Last but in some ways most important of all was the mother, who was affectionately known to everybody as Mrs. H. In fact, the whole group was always called simply "the H family," and whether they had a sur-

name or not I do not know. The really striking thing about the family was not what they were named but what they did. They had a game that they always played when they went walking together. I suppose that all of us have played this game in boyhood, but probably only in a haphazard sort of way You walk along the road and as you walk you kick the little stones that lie in your way, taking them in your stride and noticing how far they go. This was the game played by the H family; but there was nothing haphazard about their method of playing. They had a definite and unvarying procedure and they observed three rather precise conditions which were as follows: (1) They all walked at the same rate but their steps were of different lengths Henry's step was six feet, Hal's was three feet, Harry's was two feet, and the steps of little Harriet were only one foot Each member of the family kept to his own length of step and never varied from it. Henry set the pace, which was just six feet a second, neither more nor less. (2) They walked with a sort of limp that made them look as though they were cantering. This was due to their always taking the step in advance with the right foot, which was the one with which they kicked the pebbles, and they merely brought the left foot up even with the right instead of advancing it in turn as in a regular walk. (3) They wore rubber-toed shoes, so constructed that each pebble that was kicked absorbed all the energy of the step regardless of whether the impact occurred early or late in its progress. This necessitated a fresh initiating effort for the next step but produced the same effect on the pebble as if it had been kicked by the foot when moving at a speed equal to its average speed.

It was a delightful experience to see the H family coming down Main Street of a Sunday morning playing their jolly game. Henry's appearance was comical in the extreme, for he wore an expression of preternatural solemnity due to his intentness upon keeping the pace at exactly six feet a second, which happened to be the legal speed limit of the town and was never exceeded by any one. But Hal and the children were very gay and kicked all the pebbles that they could find so long as they could take them in their stride and without deviating. The funniest sight of all was Mrs H, who, though she did not play the game herself, managed to cooperate in a most important way She had come from a famous mathematical family, the Plancks of Berlin, I believe, and had inherited a passion for exact measurement. So with surprising agility she went scampering along in front of the rest and by the aid of a queer little contraption that she had devised she measured the mv^2 of most of the stones that were kicked The results of these measurements were really astonishing and filled the town's population with wonder and perplexity.

In the first place they showed that Harriet's kicks were the hardest of all. Each of her steps was only a foot in length, but her stones had twice the energy of those of Harry, whose steps were two feet long, and three times the energy of those of Hal, who took a full yard in each stride. I must remind you again that the family never varied the differing lengths of their respective steps any more than they varied their speed of progress, though that was the same for all. Now, on comparing the results of the measurements it was found that if you multiplied the *energy* of any pebble by the *time* occupied by the step of the one who kicked it you always got the same result, no matter whose pebble you were considering. Harriet, for example, took six steps to the second, so that the time occupied by each of her steps was one sixth of a second. For

the same reason the time of Harry's two-foot step was one third of a second and of Hal's three-foot step was one half of a second. If we represent the energy of Hal's step (as measured by the energy of the pebble which absorbed it) as 2e and multiply it by the one half of a second or unit of time, t, which his step occupied, the product $\frac{1}{2}t \cdot 2e$ will equal *et*. Harriet's step-energy was, as we saw, three times that of Hal's, *i.e.*, 6e. But 6e multiplied by $\frac{1}{6}t$ equals *et*. And as for Harry the energy of his step was only half that of his sister's, *i.e.*, $\frac{1}{2}$ 6e = 3e, and 3e multiplied by $\frac{1}{3}t$, which was the time taken by Harry for one of his steps, is again equal to *et*. The members of the H family were very much pleased with this result. It gave them a new sense of solidarity that made up for the bewildering and rather distressing differences in the energies of their several kicks. They decided to call the new quantity by the family initial, h, uncapitalized, of course, because it did not represent the first letter of any particular person's name; it was just the family constant.

Quantities of this kind that are got by multiplying energy by time are called "Action." Now in the year in which these happenings occurred there was much talk about Time as a sort of fourth dimension being bound up with Space in somewhat the same way that one spatial dimension is bound up with another. And many people had a queer deep feeling that the hybrid category of *Action* was more fundamental than energy itself, and that in some strange way it bore witness to the new union of space and time in a four dimensional continuum of space-time.[1]

It was easy for all of us to see that if the energy of each step of a member of the H family when multiplied by its time produced the quantity *h*, then conversely the energy itself could be expressed as the product of *h* and the reciprocal of the time, which latter will coincide with the frequency or number of steps per second, usually symbolized by the Greek letter nu. For if $et = h$ and $t = \frac{1}{nu}$ then $e \; \frac{1}{nu} = h$ and $e = h$ nu. Thus Harriet's time for a step being one sixth of a second, the reciprocal of which is 6, her energy will be equal to 6h. With Harry and Hal the frequencies will be 3 and 2, respectively, and the energies of their respective steps will be 3h and 2h; and in general the energy of any such step will be expressed by the equation $e = nu \;\; h$.

But just what was the real nature of this *h* and why did multiplying it by the frequency of the step give the energy of the step? In other words, why should the energies severally associated with the members of the H family be the reverse of what you would naturally expect, Harriet's more than Harry's and his more than that of his tall cousin? These questions fascinated me and I kept thinking about them when I ought to have been doing my regular stuff. At last I determined to get a stop-watch and check up on the various factors involved in the situation. Thus equipped I took up a good position on the sidewalk and observed very closely the steps of the family as they cantered past me. I noticed how much more quickly Harry and Harriet completed their steps than Hal and Henry; but of course that increased quickness of stepping didn't explain anything, because the steps of the little ones were that much shorter. Why should Harriet increase her energy by

[1] "Multiplying [energy] again by hours would seem a very odd sort of thing to do, but it does not seem quite so strange when we look at it in the absolute four-dimensional world. Quantities such as energy which we think of as existing at an instant belong to three-dimensional space and they need to be multiplied by a duration to give them a thickness before they can be put into the four-dimensional world."

See Eddington: "The Nature of the Physical World" (p. 180).

making a step six times as quickly as her father if in that step she only went one sixth the length of his step? But one day I got a clue. I noticed that the time taken by each step was divided into a *resting-time*, during which the foot was on the ground, and a *going-time*, during which it was moving through the air. Though each of Harriet's resting periods was actually shorter than that of the others, nevertheless there were more of them, and in proportion to the total time of her step each of her resting periods was longer than that of the others. I worked on this aspect of the situation, with my stop-watch recording the moving-time and the resting-time for the various steps, and this was what I found. Henry's resting-time was a very small fraction of a second, which for simplicity I will designate by the letter R. His going-time was consequently $1-R$, and the velocity of his foot while it was moving was therefore $\frac{6}{1-R}$ feet per second. The going-time of Hal, who took two steps per second, was $(\frac{1}{2})^2$ $(1-R)$ in each step, so during the entire second he was on the go $2\ (\frac{1}{2})^2\ (1-R) = \frac{1}{2}\ (1-R)$; in other words, for just half the time during which his Uncle Henry's foot was moving, so that in order to keep up with his uncle his foot had to move just twice as fast as the latter's foot. Harry, who took three steps a second, was on the go $(\frac{1}{3})^2$ $(1-R)$ in each step and hence $3\ (\frac{1}{3})^2 \cdot (1-R) = \frac{1}{3}\ (1-R)$ in each second, which meant that having exactly one third of his father's traveling time he had to travel three times as fast. In the same way, Harriet's total traveling time was $6\ (\frac{1}{6})^2$ $(1-R)$ or just one sixth of Henry's traveling time, with the result that if she herself was to go as fast as her father, her foot had to go six times as fast as his foot. In short, I discovered the general law that I had been searching for. In any family of steppers like the H family there is an *internal velocity* of each stepper which is proportionate to the frequency of his steps per unit of time and hence can be obtained by multiplying that frequency by the *internal velocity* of a leader or Standard Stepper whose frequency of stepping is one per second. Let us denote the *internal velocity* of the standard stepper (whether actually existing or only potential does not matter) by $V = \frac{C}{1-R}$, where C is the length of the standard step and R is the portion of the unit of time during which the foot is at rest and therefore (1–R) the time in which the foot is moving. Then, using v to denote the *internal velocity* and *nu* to denote the frequency of any other stepper, we have as a true equation

$$v = nu\ \ V \text{ or } v = nu \cdot \frac{C}{1-R}$$

In the light of this equation it was no longer surprising that little Harriet kicked her pebbles the hardest of all the family, for her feet moved the fastest not *in spite* of but *because* of her steps being the shortest. Harriet was indeed like an automobile which had to make an average speed of sixty miles an hour, but which had to stop for traffic lights every ten miles. You can imagine how much faster such a car would have to travel in between the stops, as compared with another car making the same general average of sixty miles an hour but only obstructed by traffic lights once each sixty miles. The average "internal velocity" of the former car, by which I mean the velocity *between each of its stops*, would be six times as fast as that of the latter, and the energy which it would impart to either a pebble or a pedestrian that got in its way would be correspondingly greater and sadder.

I was feeling very happy over this analysis of the situation, knowing as I did that when a thing's velocity increased it gained in energy, when sud-

denly all my happiness vanished and I spent a most perplexed and disconsolate half hour. For it came over me that while the velocity of the step varied with its frequency the energy of a moving thing varies not with the velocity itself but with the velocity squared. It was such an oversight as only a child would make and my chagrin and humiliation were bitter indeed. And then suddenly I was all right again, for I bethought me of a perfectly obvious fact that I had completely forgotten to take account of, the fact, namely, that the *mass* of the leg and foot of the stepper varied directly with the length of his step or inversely with its frequency. The tiny leg and foot of Harriet, for example, were one sixth the mass of her father's, Hal's were a half, and Harry's were a third of that mass, therefore the energy mv^2 will increase with the *first* power of v because the other power of v will be neutralized, so to speak, by the decrease of the mass m. Thus, if we call Henry's energy in each step mv^2 and if we bear in mind that the mass factor in Harriet's step is $\frac{1}{6}m$, in Harry's $\frac{1}{3}m$, and in Hal's $\frac{1}{2}m$, then Harriet's energy will be symbolized by $\frac{1}{6}m(6v)^2 = 6mv^2$; Harry's will be $\frac{1}{3}m(3v)^2 = 3mv^2$; and Hal's will be $\frac{1}{2}m(2v)^2 = 2mv^2$; and in general the "step-energy" of any member of the family will be $\frac{1}{nu}\,m(nu \cdot v)^2 = nu \cdot mv^2$.

Up to now we have not spoken directly of the energy of Henry's steps. Whether from an old-fashioned conjugal piety or from some special difficulty, real or imagined, Mrs. H. never measured the energy of her husband's steps as contained in the pebbles that he kicked. But if she had she would of course have found them in agreement with the general formula

$$e = h\,nu$$

And as in Henry's case $nu = 1$ his step-energy was h times 1 or simply h. In short when *energy* is multiplied by *time*, and *time* is $1/nu$, and *nu* is 1, then the product of *energy* and *time* is the same as—or is measured by the same number as—the energy itself. Of Henry we may say that his *energy* and his *action* were the same thing, namely *h*. Now it is all very well to call Henry's step-energy *h* and to note that the step-energies of the members of his family were all discrete multiples of that energy, *nu*, the discrete multiplier, being the frequency which determined the velocity which determined the energy of movement within each step. But we must also remember that Henry's energy, like all energies, can be expressed as one half the product of a mass and the square of its velocity. Hence we can call Henry's step-energy not only h but $\frac{1}{2}mv^2$; and we must ask what is the *m* and what is the v^2 which when multiplied together and divided by 2 are equal to *h*. The mass factor is of course the mass of Henry's leg and foot, and we will not bother about that just yet, as it pertains too exclusively to the secondary details of our story. But the v^2 is more important because it is the square of the velocity of a step *whose internal speed is critical in any given system of measurements*, being the speed of the step of a person who takes but a single step in each unit of time.

My fable has been long, but its application can be very brief. The H family, or rather the steps taken by its members, are of course the fictional analogue of the family of light-waves which range in length and frequency from the longest of the radio waves to the shortest of the gamma waves. They all travel at the same constant velocity, which is, however, not 6 feet a second, but 300,000 km a second.

The pebbles that were kicked off the ground and that received and registered the energy of the stepper who kicked them, are the electrons that are knocked off the photoelectric screen with a velocity that embodies the energy of the impinging light-waves. As Mrs. H. in

the fable measured the energy of the pebbles—and hence of the steps which caused their motion—by her "contraption," so does the physicist, by compelling the electrons to pass through his magnetic and electrostatic fields, succeed in measuring *their* energy and hence indirectly the energy of the light-waves which caused their motion. Corresponding to Henry with his six-foot steps there is a potential light-wave whose frequency would be one a second, whose length would be 300,000 km and whose energy would be the real *h* as the energy of Henry's step was the fictitious *h* There is nothing intrinsically peculiar about this wave as such, but in our system of measurements it is most peculiar because its energy will figure as the mysterious unit of which the energy of all other waves will be discrete multiples, as expressed in the famous equation $e = nu \cdot h$.

The energy of the standard or unit wave will be $\frac{1}{2} M \left(\frac{C}{1-R}\right)^2$, where C is of course the velocity of light, R the resting-time of such a wave, (1–R) its going-time, and consequently $\frac{C}{1-R}$ its internal velocity.

As for the mass factor, M, it would be a real but periodically intermittent condensation (186,000 miles long) of the ether that was dear to Queen Victoria and her subjects. But if any one thinks that it would be better to describe this real but regularly intermittent mass-factor in a light-wave as a periodically recurrent non-Euclidean warp in space or space-time he is welcome to do so.

My theory can be summed up as follows: All light-waves have the same *external velocity* or speed of propagation, but each of them has an *internal velocity* and hence an internal energy that is different for different waves, being proportionate to the frequency or shortness of the waves in question. The validity of this conception rests upon my fundamental hypothesis that a light-wave is analogous to the step of a man walking in a certain manner, in that its total period is divided into a *resting-time* which intervenes between the successive steps or pulses of propagation, and a *going-time* in which the *internal velocity* of the pulse or step passes from zero to its maximum and back to zero. The greater the frequency of a wave per second the greater the number of its resting periods *during* that second, and the less the time that is left in which to do its traveling, and hence the faster it must go if it is not to drop behind. In short, if a wave of frequency *nu* is to keep up in the procession with all waves and in particular with a standard wave whose frequency is one per second, its individual pulses will have to go *nu* times as fast as those of the standard wave. Its average *internal velocity* will thus be measured by its frequency, and its resulting energy will equal one half the product of its *internal velocity* squared and its mass. But if the mass-factor of a wave does itself vary inversely with its frequency, which was our assumption, then its energy will be equal, not to the second power, but to the first power of its frequency multiplied by the energy of the standard wave. If Planck's mysterious constant *h* is simply the energy of the standard electromagnetic wave of unit frequency then the energy of any other wave will be *nu* times h. My assumption that the mass-factor varies inversely with the frequency and directly with the length of a wave is not an arbitrary one, because the shorter the wave the less the volume of spatial field that undergoes the periodic concentration or warpage that constitutes the mass-factor of a wave. Our theory suggests the curious possibility of there being a quantum, or something analogous to it, in every system of waves.

Having now stated my interpretation

of the nature of *h* and the reason for the equation e = h · *nu,* I turn to the second of the three problems of the Quantum.

II. The Reconciliation of the Undulatory and the Corpuscular Aspects of Radiation

Something happens within an atom and immediately there is emitted from it radiant energy which travels away from its source with a velocity of 300,000 km per second. These units of radiation possess many of the characteristics of waves or periodic changes. Not only do they seem to be of different length and frequency and to travel always at the same rate, regardless of the motion of their source, but they exhibit the phenomenon of interference, counteracting and enhancing one another. Now if a wave goes out in all directions from its source, we can think of it as spread over the surface of a sphere, a sphere that is expanding with the speed of light. One would suppose that the intensity of such a wave should vary inversely with the square of its distance from its source Covering a larger and larger area as its distance grows, there will naturally be less and less of it for each unit of area. Sooner or later a physicist will hold up a photoelectric screen and tap this wave to test its energy. The source of the wave may be at the other end of his laboratory or at the other end of the Milky Way, but in either case the entire energy that issued from the atom will be instantly mobilized from all over the spherical surface of the advancing wave and delivered intact to the electron whose movement will record the transaction and the amount received. Now when one tries to think of this instantaneous reconcentration of energy, imagination is challenged and reason baffled to an extent unparalleled in the history of science. Sir William Bragg has aptly compared the situation to one in which a wave is aroused by a log dropped into the water and spreads out for miles in an ever-widening circle of ever-diminishing intensity. Finally this ripple comes into contact at one point of its vast circumference with another log and suddenly reassembling all its scattered energies shoots it up into the air with a force as great as that possessed by the original log which far away and hours ago had started the process.

Confronted with such a paradox we tend to abandon the conception of light or radiation as consisting of *waves* at all. The fact that distance has no effect on the energy suggests that light is composed of some kind of corpuscles. If that were so we could understand how these corpuscular elements of radiation, being unretarded by friction, could maintain unchanged their velocity and therefore their energy throughout any distance. As to the fact that while their energy does not depend upon their nearness to the source it does depend upon their shortness or frequency—we might at least hope to interpret that as due to discrete differences in the mass of such corpuscles. The so-called shorter light elements might, for example, contain proportionately larger multiples of some ultimate unit of radiant mass. What we call the *intensity* of the radiation or the brightness of light would then be purely a *group-phenomenon,* due to the number of corpuscles that in a unit of time impinged on a unit of surface. And this number would vary inversely as the square of the distance, as intensity or brightness should do. From such a theory it would follow as a corollary that the intensity of light would be increased either by increasing the number of radiating units at the source or by lessening the distance of the recipient from the source; and the effect of such increased intensity on the photoelectric screen would be what as a fact we find it to be, namely, an increase in the

number of electrons shot off and not an increase in their *velocity*.

The corpuscular theory, however, while thus capable of explaining many of the properties of radiant energy, still appears incapable of explaining such ineradicably undulatory properties as interference of radiations with one another and the continuity of their incidence upon a receiving surface such as the lens of a telescope. If light consisted of separate corpuscles their increased distance from one another as they diverged or scattered from their center of origin (like a charge of bird shot from a gun) should become sufficiently great to make its effect appreciable in the form of gaps or discontinuities to an observer who was as far from some of the observed stars as we are. But though such an effect has been looked for, it has not been found. Light from the most distant sources preserves its continuity of frontal surface just as little waves would and just as little corpuscles wouldn't and couldn't.

There is moreover against this corpuscular theory another objection, which is interesting in itself and which possesses at least an *ad hominem* force. *If light were composed of corpuscles, either the Ritz Hypothesis would be true or else the Doppler effect would be a one-way affair and would reveal to us an Absolute Motion expressed as an empirical difference between the situation in which a luminous source moves toward an observer, and the reverse situation in which the observer moves toward the luminous source.* For in the latter case we should meet the light corpuscles with more force than if we stayed still, and thus be able to observe an increase of their energy as a Doppler shift toward the violet. But if the light-giving object was moving toward us and if the speed of the corpuscles emitted by it was unaffected by the speed of their source they would reach us in greater *number* per unit of time but not with greater individual *velocities*. And thus the photoelectric screen would fail to register any shift toward the violet. The only way to lay the specter of Absolute Motion would be to accept Ritz's Hypothesis that light being corpuscular, its velocity, like the velocity of an ordinary projectile, varies with the velocity of its source. It would *then* make no difference whether we moved faster toward the corpuscles or whether they moved faster toward us. The shift toward the violet would in the two cases be equally observable in the increased energy of the individual electrons that were knocked off the photoelectric screen. But this way of restoring symmetry to the Doppler effect would be spurned by most physicists and astronomers. For whether they are Einsteinian Relativists or Newtonian Classicists they appear to agree in believing that De Sitter's deductions from the observations of double stars, as well as certain recent observations of the aberration of light from distant nebulae, are conclusive disproof of the assumption that the velocity of light varies with the velocity of the source. To all believers in Einstein's Special Theory of Relativity the implications of the corpuscular theory for the Doppler effect should have a fatally decisive though *ad hominem* force. For in accepting the corpuscular theory they would have to couple their acceptance either with a belief in the Ritz Hypothesis or with a belief in Absolute Motion.

The whole situation is in a sense desperate. And desperate situations call for desperate remedies. One such remedy is characterized by Sir Arthur Eddington as the Sweepstake Theory. The situation that leads to the theory and the theory itself are set forth by him in "The Nature of the Physical World" (pp. 185–190), from which I quote the following passages:

> The pursuit of the quantum leads to many surprises; but probably none is more out- ...our preconceptions than the regath-

ering of light and other radiant energy into h units, when all the classical pictures show it to be dispersing more and more. Consider the light-waves which are the result of a single emission by a single atom on the star Sirius. These bear away a certain amount of energy endowed with a certain period and the product of the two is h. The period is carried by the waves without change, but the energy spreads out in an ever-widening circle. Eight years and nine months after the emission, the wave-front is due to reach the earth. A few minutes before the arrival some person takes it into his head to go out and admire the glories of the heavens and—in short—to stick his eye in the way. The light waves when they started could have had no notion what they were going to hit; for all they knew they were bound on a journey through endless space, as most of their colleagues were. Their energy would seem to be dissipated beyond recovery over a sphere of 50 billion (10^{12}) miles radius—How is it managed? Do the ripples striking the eye send a message round to the back part of the wave saying "We have found an eye, let's all crowd into it!". . . . Suppose that the light-waves are of such intensity that, instead of each atom absorbing one millionth of a quantum one atom out of every million absorbs a whole quantum. That whole quanta are absorbed is shown by the photoelectric experiments already described.

It would seem that what the light-waves were really bearing within reach of each atom was not a millionth of a quantum but a millionth chance of securing a whole quantum. The wave-theory of light pictures and describes something evenly distributed over the whole wave-front which has usually been identified with energy. Owing to well-established phenomena such as interference and diffraction it seems impossible to deny this uniformity, but we must give it another interpretation; it is a uniform *chance of energy*. Following the rather old-fashioned definition of energy as "capacity for doing work" the waves carry over their whole front a uniform chance of doing work. It is the propagation of a chance which the wave-theory studies.

Now there are two objections to this Sweepstake Theory. First there is the one which Eddington himself goes on to state, but which I take the liberty of presenting in my own words. How does it happen that the first atom to touch the expanding spherical surface of probability-waves always draws the winning ticket and receives the prize of actual energy? If a conjurer on the stage threw out over the heads of his audience a scattering pack of cards, and if the member of the audience who caught the first card regardless of where he was sitting always found it to be the ace of spades, we should have to draw one of two conclusions. Either the conjurer had this man "planted" in the theater as a confederate and knew just where he was sitting, or else every card in the pack was an ace of spades. The latter conclusion would be barred out by making sure (as we actually do) that the conjurer had only one of the prize-winning aces in each pack that he threw out. The other conclusion as to the presence of a confederate would remain. And it would have its analogue in the fascinating but ultra-quixotic theory of Gilbert Lewis, that an atom can not muster up courage to emit a vibration until it knows exactly where and when that vibration will be received. The recipient scientist with his eye or his photoelectric screen may be trillions of miles away in space and not due to be born for hundreds of years after the light issues from the star. But according to the Special Theory of Relativity, in the case of a light ray, the spatial and temporal distances cancel one another, $ds^2 - dt^2 = 0$, and between the start and the finish of the ray there is a kind of contact in space-time, a mystical *rapport*, which is the basis for Lewis's feeling that the atom must "know" where its light will land before it emits it. I do not know what Lewis would say to the case of a physicist who, having read his theory, decided to thwart destiny and instead of holding up his photoelectric screen at the time and place he had intended before reading should decide to leave the date and location to be determined by the throw of dice. I should think Lewis would have to say of such a situation that Fate could not be thus circumvented and that the prophetic insight of the atom in the distant galaxy would have been so keen that it would

have foreseen or seen through the reading of Lewis' book by the scientist, the casting of the dice, and their resulting configuration determining the time and place of the electronic recipient of the light—despite the fact that all these events happened "after" the light had been irrevocably started on its journey. Now, notwithstanding my friendship and high respect for Gilbert Lewis, I must really ask to be excused from believing this. If it is true, as Lewis believes, that such an absurdity is actually implied by Einstein's Special Theory, then all I can say is, "So much the worse for the Special Theory."

But even if we waive this objection to the Sweepstake analogy we are immediately confronted with another: What is to become of all the other chances of energy that have been propagated from the atom after the winning chance has been actualized? Lottery tickets that have been declared unsuccessful are at least worth the paper they are printed on and they continue to occupy space, albeit in the scrap baskets of their unsuccessful owners. But these unsuccessful *probabilities* that have been traveling outward with the velocity of 186,000 miles a second and that are dispersed over the surface of the huge sphere have nothing to do and nothing to be. They lapse into absolute nonentity on the instant that the lucky ray conveys its freight of actual energy to the receiving electron.

In view of all this it seems to me that the Sweepstake Theory completely fails and that, as Sir William Bragg has so happily phrased it, we are left with the necessity of teaching the classical theory of light on Monday, Wednesday and Friday and the quantum theory on Tuesday, Thursday and Saturday. Both can not be, and each must be, true. Such a situation is so outrageous that no one, not even the most extreme positivist or empiricist can "take it lying down." Any one who has in the veins of his mind a single drop of the red blood of reason must demand satisfaction in the form of some conception of what it is that is really happening to produce these seemingly incompatible sets of appearances.

When doctors disagree or fail to cure there is a chance for the quack to peddle his nostrum, and as a poor but honest quack I want now to proffer my nostrum. At worst it will do no harm.

Let us suppose that the mysterious entity that issues from an atom is a condensation in the ether (or a non-Euclidean warp of "space"), that is shaped like a cone but with so slender an angle of divergence as to approximate a cylinder, and that it moves outward from the atom at the speed of light. The path of this movement or the volume generated by it is a conical sector of a sphere whose center is the center of the nucleus of the initiating atom and whose base or advancing frontal surface is as distant as may be. The movement outward through the volume of this expanding cone is a periodic movement. It is the movement of an advancing wave. I shall assume that this movement consists of progressively alternating "twist-thrusts" like those of a cork-screw—clockwise then counter-clockwise, then clockwise, then counter-clockwise, and so on.

Perhaps I can bring my idea more clearly to your minds if I simply ask you to picture a long slender cone cut transversely into sections of equal length but remaining *in situ*, *i.e.*, as they were before they were cut. Paint these sections alternately black and white and think of their contact surfaces as possessing a cog-like mechanism such that shortly after the right-hand or clockwise twist-thrust of one completes itself there will begin a counter-clockwise twist-thrust in the next. Then imagine the series of periodic and alternating

twist-thrusts to start from the apex of the cone and travel outward, and the thing that you would see advancing outward and expanding as it went along and through the whole cone would be the kind of thing that according to my hypothesis a light-wave is—a thing that would wriggle or worm or *squirm* its way through space at a velocity of 186,000 miles a second. Let us call the light-wave as thus conceived a "squirm." Squirms could be of various lengths, as light-waves are; and while the speed of the procession as a whole would be the same, irrespective of the length or correlated frequencies of the constituent squirms, the *internal velocity* of each squirm (which is the measure of its energy) would vary inversely with its length and directly with its frequency. For just as in the family of steppers in the fable, with which my paper began, the total period of each squirm would be divided into a *going-time* and a *resting-time*. The shorter the squirm the greater the number of its resting periods and hence the faster it would have to go during the time when it was going. And as the mass of a squirm varies inversely with its *internal velocity,* the internal energy or mv^2 of the squirm varies directly only with the first power of that velocity which is in turn determined by its frequency and will therefore be expressed by multiplying its frequency, *nu,* by a constant. That constant is *h*, which is the unit energy of the standard or critical squirm which in our system of metrical units has a length of 300,000 kilometers and a frequency of one per second. All squirms of frequencies greater than one or multiples of one will have energies that are corresponding multiples of *h*.

Now the foregoing characteristics of the light-squirms as to mass, length, frequency, external velocity and *internal velocity* are characteristics which they share with all waves.

First, though the mass of any squirm is a function of its length and hence remains unchanged no matter how far out from their source squirms of a given length (that of red light, for example) may have traveled, yet the *character* of the mass changes; its density or intensity of concentration decreasing as its volume increases, for it is obvious that the truncated sections of a cone, if they are of constant length, take up more space the further they are from the apex.

Second, a squirm of radiant energy, as I conceive it, will "vibrate" in a direction nearly but not quite perpendicular to its direction of propagation. But this so-called vibration will consist of alternating rotations or twists which will lie in the ever-varying plane of a shallow whorl to which the "ray" or longitudinal dimension of the cone is almost normal. Hence, when a squirm strikes the electron on the photoelectric screen it will cause it to move off sideways rather than in the line of the light ray.

Thirdly, the advancing front of the squirm will occupy the same proportion of the surface of a sphere at one distance as at another. And a group of squirms going out from a light-emitting center will always remain as adjacent to one another as they were at the start. They will not possess the fatal capacity to scatter that disqualified the corpuscular hypothesis. They will be true waves, and as such they will exhibit the requisite phenomena of undulatory interference, no matter how far from their source. But at the same time that they preserve their continuity as a group they will also preserve their quasi-corpuscular discreteness and integrity as individuals. The squirm is not only "big" enough to enter the astronomer's telescope in the way it does, it is also "small" enough to be sucked in by the electron on the photoelectric screen of the physicist. No

matter how large its frontal cross-section and the radius of its twist may be, the twist itself will be as much of a single unit as when it was first emitted and as such can impart all its energy to the electron almost on the instant of contact with the same ease with which a large top could impart its energy of spin to a small object with which it came into fatally intimate contact and in such a way that what was velocity of spin in the giver would become velocity of translation in the receiver.

In short, because of its seemingly harmonious combination of the undulatory characteristics of classic light with the corpuscular characteristics of quantic light, I respectfully nominate my "squirm" as a candidate for the high office of "wavicle," the felicitious name suggested by Eddington for that blend of wave and particle which is the great desideratum for light as known to-day. It was the reconciliation of these apparently contradictory properties of radiation that constituted the second of our three problems of the Quantum. Let us now turn to the third and last of the puzzles—the nature of the emitting atom, tiny source of all the mischief

III. The Nature of Atoms and the Manner of Their Discrete but Continuous Emissions

I accept the hypothesis proposed by Professor Louis King and by other physicists that the electrons spin or rotate on their axes. I supplement this hypothesis with the further one that the *protons* also spin, and I propose to employ these hypotheses in a manner that so far as I am informed has not been suggested before.

An electric charge in rotation becomes a magnet with a north pole and a south pole. Hence the spinning protons and electrons are related to one another by magnetic as well as by electrostatic forces. There are of course an infinity of angles possible between the axes of any two such spinning particles, but I wish to limit my discussion to the single case in which the axes of spin are exactly, or very nearly, in line. I adopt this limitation partly to avoid unmanageable complexities and partly because I suspect that two spinning charges, freely interacting, would arrive at this configuration sooner or later whatever might have been the initial inclination of their axes in relation to one another. Observing this limitation, we can picture our pair of spinning particles with their axes end to end or like a pair of spinning tops one above the other; and there would then appear to be four different situations to be taken account of.

(1) Two particles of dissimilar electric charge with similar magnetic poles adjacent.

(2) Two particles of dissimilar electric charge with dissimilar magnetic poles adjacent.

(3) Two particles of similar electric charge with similar magnetic poles adjacent.

(4) Two particles of similar electric charge with dissimilar magnetic poles adjacent.

These situations may be symbolized thus:

	S		N		S		S		N		N
	−		−		+		−		+		−
	N		S		N		N		S		S
1	N	2	N	3	N	or	N	4	N	or	N
	+		+		+		−		+		−
	S		S		S		S		S		S

In analyzing these four situations there is a most important principle which we must keep before our minds:

When the dimensions of two magnets are negligibly small in comparison to the distance between them, the magnetic force, whether of attraction or repulsion, varies inversely not with the second power but with the third power of the distance of the magnets from one another.

Inasmuch as the *electrostatic* force of attraction or repulsion varies inversely with the *square* of the distance it follows that for our particles, which are both charges and magnets, the electrostatic force will be the dominant determiner of behavior at relatively large distances (the magnetic force diminishing more rapidly with increase of distance than the electric) while at relatively small distances the magnetic force will be the dominant determiner of behavior, for it will increase more rapidly than the electric force with the decrease of distance; and finally, *when the electric force is attractive and the magnetic force is repulsive,* there will be a critical distance at which the two forces will balance.

In the light of these facts we can see at once that in situation number 4 the two protons or electrons, if by themselves and uncemented by a third particle of opposite charge between them, will repel one another and execute an unending reciprocal retreat; for they would ordinarily never have a chance to get near enough to have their magnetic attraction dominate their electric repulsion.

In situation number 3 where the two similarly charged particles suffer at all distances a double repulsion, both magnetic and electric, their retreat from one another will be even more obvious.

In situation number 2 we have the reverse of number 3 Instead of suffering a double repulsion the dissimilar electric charges with their dissimilar magnetic poles adjacent will enjoy a double attraction and will cuddle close into a nuclear nest.

We now turn to situation number 1, which is by far the most interesting of the four that are listed in the diagram. Here we have two particles with dissimilar charges but with similar magnetic poles adjacent. We have already remarked that such a blend of electric attraction and magnetic repulsion means that when the distance separating the particles is great the electric force will predominate and the particles will converge; but when the distance is small the reverse will be true, magnetic force will predominate and the particles will diverge. Between the "great" distances and the "small" distances there will, however, be an intermediate distance at which the opposed tendencies will just balance. In the hydrogen atom, for example, with its single proton as nucleus and its single "planetary" electron there will be a critical distance between them, at which the magnetic repulsion will equal the electrostatic attraction. Representing this critical distance by D, the magnetic force by Fm, and the electrostatic force by Fe, we have

$$\frac{Fm}{D^3}=\frac{Fe}{D^2},\ Fm = D \cdot Fe,\ D=\frac{Fm}{Fe}.$$

If by some external influence the distance of the electron from the nucleus is made longer, the magnetic repulsive force will decrease more rapidly than the electrostatic attractive force, and therefore the electron will tend to snap back inward. If, on the other hand, the distance is made shorter, the magnetic repulsion will increase more rapidly than the electric attraction and the electron will tend to snap back outward. The two elements of the system, united as they are by their diverse forces, will constitute a sort of coiled spring such as one finds in chairs and sofas. It will offer resistance both to compression or shortening and to expansion or lengthening. This resistance will be as gentle as you please for slight changes in either direction, and proportionately stronger for greater changes.

I wish now to pass from these deductions from my primary hypothesis and to propose certain further and secondary hypotheses. I make these subsidiary hypotheses or guesses very diffi-

dently and in the hope that if some or even all of them should prove to be not good they may nevertheless suggest to those more competent than myself hypotheses that will be good.

First, then, let us suppose that the proton-electron system above described can vibrate in halves, thirds, quarters, fifths, etc., of its length. Such vibrations we will call its "tones." And we will assume further that the system can entertain at least for a time several or all of them simultaneously, as a superposed hierarchy of periodic motions.

Secondly, let us suppose that that which in the first section of our discussion we called the "internal velocity" of the step or wave varies (when *within* the spring) *not inversely but directly* with the length of the step or wave. So that when the spring was vibrating in thirds, the *internal velocity* of those vibrations would be as much greater than the *internal velocity* of vibrations that were fourths as one third is greater than one fourth, and in general that the *internal velocities* of vibrations whose lengths were $1/n$ and $1/(n+r)$ would be to one another as $1/n$ is to $1/(n+r)$. This is not as arbitrary a supposal as it might seem, for it is certainly true that the further you jam down (or stretch up) a coiled spring the harder and faster it will fly back. The greater the length of the periodic displacement the greater the velocity of return.

Thirdly, let us suppose that the mass factor in these periodic movements does not vary directly with the length, and inversely with the internal speed, as in the case of the light-waves outside the atom, which we discussed previously, but that it is *constant*. It will be as though the mass of the whole system entered into each and all of its vibrations.

Now let us examine the implications of our supposals or postulates. We notice that if the atom be conceived as a spiral spring, its vibrations are in their lengths and velocities

$$1/1,\ 1/2,\ 1/3,\ \ldots$$

which means that the energies of these vibrations will be the products of a mass factor, M_p, characteristic of the spring itself, and the squares of the several velocities; thus

$$E = \tfrac{1}{2} M_p \left\{ (1/1)^2,\ (1/2)^2,\ (1/3)^2 \right\}$$

These energies will travel in both directions, up and down the spring, from the nucleus out to the electron, and back in from the electron to the nucleus. Now any one of these vibrations, if left to itself, would go like a shuttle-cock between two battledores, peaceably outwards and back through the spring forever. There would be no friction to slow it down and no way for it to *get out*. But when one vibration meets or overtakes another of a different length and rate—what then? Well, if the interference occurred within the atom, *i.e.*, between the nucleus and the electron, I suppose that they would pass right through each other as proper waves do, and be none the worse for it, their integrities remaining unscathed by their transitory union. Perhaps one of Maxwell's demons, if he lived in the atom, might hear some beats or difference-tones, but that would be all. Nothing would get to the ears of the outside world. But now suppose that their interference occurred at the electronic terminus of the trip. The vibration $1/n$ just arriving meets the vibration $1/(n+r)$ which is just starting back. The electron which constitutes the outer end of the spring can not accommodate the two vibrations by moving in opposite directions at the same instant. The situation is serious, and so far as I can see, the lesser vibration, whose energy was $\tfrac{1}{2} M_p \cdot \left(\frac{1}{n+r}\right)^2$, would neutralize such part of the stronger vibration as was

equal to itself, leaving an unneutralized remainder whose energy would be equal to $\frac{1}{2} M_p \cdot \left\{\frac{1}{n^2} - \frac{1}{(n+r)^2}\right\}$. This remainder, a sort of "difference-tone," would have nothing to do but *slip off into space*, as a new-born squirm or light-wave, and go on about its business The energy of the young squirm, like that of any squirm, would be equal to Planck's constant, h, multiplied by its own frequency, *nu*. But as witness to the values of its parents of whose unhappy union it was the fruit, its energy would also be equal to $\frac{1}{2} M_p \left\{\frac{1}{n^2} - \frac{1}{(n+r)^2}\right\}$, where n and r are any positive integers.[2] The factor M_p would have just the value that was necessary to make h *nu*, the "difference-tone," equal to the *difference between* the two "tones," $\frac{1}{n}$ and $\frac{1}{n+r}$, from which it originated. And that value would be characteristic of the type of atom emitting the radiation. From these considerations we can see that a light-wave coming from an atom is not merely a member of the general tribe of squirms but also a member of a special family as symbolized by the subscript letters in M_p, M_q, M_w, etc. That special family in the case we are considering is the group of light-waves registering as lines in the spectrum of hydrogen. It is a large family, containing perhaps an infinite number of members. But the members are by no means a continuum composed of all possible values. They have only such values as are represented by the differences between pairs of *terms* in the series.

Let us glance briefly at the prospective history of a squirm such as the one whose birth we have described. It glides out into the ether and swims freely but in the direction determined by the line that joined the proton and electron at the instant of its leaving them. It squirms its way along, with alternating twist-thrusts, at the rate of 186,000 miles a second. Its volume gets larger as it occupies successively the larger and larger truncated sections of the cone which is its path and from whose apex it originated and toward whose infinitely distant base it travels. But this growth in volume is balanced by an equal diminution in density. As it grows bigger it becomes more and more tenuous, with the result that since its length and *internal velocity* do not change, its energy and mass also remain constant.

There are two alternative destinies in store for every squirm; one, ignominious and tragic, the other happy if not glorious. The ignominious fate that may befall a squirm is to be swallowed by an electron and utilized as food to give the electron energy of translation. In having its own periodic motion thus transformed into the electron's motion of translation, its specific structural identity is permanently lost and only its quantity is conserved—destined perhaps to be measured by a scientist if the devouring electron is located on a photoelectric screen. Let us suppose, however, that the squirm escapes this death by absorption. In the course of its travels it will meet with various atoms. In some of these atoms the defining constant, M_q or M_w (differing from its own defining constant M_p) will be such that no product of the form

$$\frac{1}{2} M_{q,\cdot w} \left\{\frac{1}{n^2} - \frac{1}{(n+r)^2}\right\}$$

will be equal to $\frac{1}{2} M_p \left\{\frac{1}{n^2} - \frac{1}{(n+r)^2}\right\}$ or the particular value of h · *nu*, which is the energy measure of the squirm in question. Atoms of this kind will neither absorb and devour our squirm, nor will they welcome him. He will be courteously turned away, and transmitted or simply reflected by them. Some day, however, he may have the

[2] I believe, however, that usually if not always r = 1.

luck to meet with an atom of his own family, a hydrogen atom, one line in whose spectrum belongs to him. It will be then that he will have recourse to his birth-certificate and recall that he is not merely $h \cdot nu$ but also and equally

$$\tfrac{1}{2} M_p \left\{ \frac{1}{n^2} - \frac{1}{(n+r)^2} \right\}$$

As such, he will enter the atom by the same type of door as that through which he came out, and be peacefully transmuted from a "difference-tone" into two "terms" or "tones" *whose difference in energy is equal to what his energy was.*

In short, atoms *give* light of a definite wave-length and frequency represented by a definite line in the spectrum by *synthesizing* their internal and self-contained vibrations, "terms" or "tones" and emitting a "difference-tone." They *receive* light-waves by *analyzing* a "difference-tone" (when it can be so analyzed) into two of their own tones. Emission is a case of

$$\tfrac{1}{2} M_{p,\,q,\,w} \ldots \left\{ \frac{1}{n^2} - \frac{1}{(n+r)^2} \right\}$$

becoming *h nu*. Reception is a case of this process reversed.

Let us conclude with some reflections upon atoms other than hydrogen, in the light of our theory of an atom as a sort of spiral spring constituted by the balance at a critical distance of two forces, a magnetic repulsion varying inversely as the third power and an electrostatic attraction varying inversely as the second power—these forces to obtain between and to originate from a positively charged and predominantly protonic nucleus that spins one way, and an oppositely situated negatively charged and exclusively electronic "planet" (or "planets") spinning the same way. By "oppositely situated" I mean, as previously stated, that a line joining the centers of the nucleus and any "planet" would be perpendicular (or more or less nearly perpendicular) to the planes of their respective rotations. The clumsy guardedness of the above statement is necessary to make the definition fit not merely the special and limitingly simple case of the hydrogen atom but the general class of cases exemplified by the other atoms, from helium to uranium.

With the protons and electrons acting alternately as a sort of cement for one another, various nuclear structures would be possible. The structure of the alpha-particle or helium nucleus seems to be the most stable; and for that reason it is an apparently universal element in all complex atomic nuclei. Such complex nuclei containing both electrons and protons might exemplify different directions of spin, but one of these directions would probably predominate. There would then be a critical distance for as many "planetary" electrons as were needed to make good the electronic deficit in the nucleus, which deficit defines the Atomic Number. The planetary electrons could not, however, all occupy the same position. They would push one another somewhat away and take their places on a shell or plane that was curved like the surface of a *parachute*. With respect to them the nuclear center would occupy a position analogous to that of the man hanging from the parachute. There might be several such shells, one beyond the other, and except in the case of hydrogen they would probably be located on both sides of the nucleus. The whole structure would thus resemble an *hour-glass*. Between the nucleus and each of the outside electrons there would exist the same sort of spring-like balance of forces as we found in the hydrogen atom. "Tones" and the "difference-tones" that were emitted and absorbed would also exist in the same way. And each atom would thus have its series of spectral lines different from, but on the same generic plan as, that of hydrogen.

If the ordinary light-waves, together with the infra-red, the ultra-violet and

perhaps the x-rays, are to be accounted for by the vibrations passing between the nucleus and the outlying or so-called planetary electrons, what provision does our hypothesis make for those very short waves such as the gamma radiation which appears to have an exclusively intra-nuclear origin? So little is known about the detailed structure of the nucleus that even the most tentative answer to such a question may seem hardly worth while. We do know, however, that the protons are for some reason nearly two thousand times the mass of the electrons and we know also that there are no atoms with negative atomic numbers; in other words, every close-packed or nuclear configuration of protons and electrons contains an excess of the former. It may be that this excess of protons over electrons in the nucleus is due to the fact that the greater inertia of two protons would cause them to separate less rapidly in response to their electrostatic repulsion than a pair of equally repellent electrons, and that it would thus be easier for one electron to cement together two protons, as in the newly discovered isotope of hydrogen, or two electrons to bind together four protons as in the ubiquitous alpha-particle, than for a larger number of electrons to be cemented by a smaller number of protons. In any event, on our hypothesis of the protons and electrons as spinning and as being therefore not merely electrostatic but also magnetic, there would be spring-like balances of repulsion and attraction *within* the nucleus as well as *between* the nucleus and the outlying electrons. And from the vibrations within these purely intra-nuclear "springs" there might proceed as "difference-tones" the gamma rays and possibly even the cosmic rays.

Although the exigencies of recent Quantum theories have required the abandonment of the attractively simple model of the older Rutherford-Bohr atom, yet unless I am greatly mistaken the relatively unpicturable conceptions of the atom to-day involve in some form the original notion of the separate orbits (with their resulting separate energy-levels) in which the electrons revolve, giving forth their discrete bundles of radiant energy by jumping from one track to another. Now it was surely bad enough that the chemists should have been forced to abandon the static type of atom which as chemists they would naturally prefer, in favor of the dynamic type which physics appeared to necessitate. And when to that disadvantage there had to be added, by reason of the Quantum phenomena, the intolerably arbitrary conception of orbits, separated from one another like *grooves*, between which the electrons must choose with no possibility of intermediate paths, the burden upon belief became almost too great to be borne. Let us then remember that apart from the purely sentimental analogy with the solar system (which for all its unworthy irrelevance may not have been lacking in an unconscious psychological effectiveness) the only reason for making the outyling electrons revolve around their positively charged nucleus was to keep them from falling into it. If it is possible by such a hypothesis as I have advanced to explain through a balance of magnetic repulsion and electric attraction the existence of electrons held at arm's length from their nucleus without the necessity of preserving their distance by the centrifugal force of planetary revolution—is that not an advantage? And if the static atom can not only then be revived, but be revived in such a form that its discretely quantic radiation can be accounted for as the "difference-tones" or terminal interferences of the various waves which, like the tones and overtones of a musical string, would run to and fro over the

spring-like *field* connecting nucleus and electrons, is that not a further advantage of sufficient promise to extenuate the crime of a layman in venturing with amateur conceptions into regions where, until further facts are known, even experts fear to tread?

I conclude these highly speculative suggestions with four still more speculative corollaries in the form of queries.

(1) Is it not possible that the wave-like behavior of particles, not only electrons and protons, but even atoms and molecules, could be explained by their postulated spins which would undergo periodic retardation and acceleration on contact with obstructions such as screens and gratings?

(2) Is it not possible that the puzzlingly excessive radiation of the stars is caused by clashes between their intrinsically spinning corpuscles rather than (as is currently supposed) by a destruction of their mass through a suicidal proto-electronic amalgamation?

(3) Knowing as we do that alpha and beta particles are expelled with enormous velocities from the nuclei of radioactive atoms, is it not possible, and even probable, that these velocities have their source in a primal energy of spin on the part of the corpuscles composing the nucleus? For when rapidly rotating particles come in contact with one another part of their energy of rotation is changed into energy of translation. Contacts of this violently disruptive type might well be periodically recurrent and would certainly be more noticeably frequent in the massive, complicated and herefore presumably unstable nuclei of dium and uranium

(4) If a light wave or squirm consisting of alternating twist-thrusts were to ncounter an obstacle that would neither ransmit nor reflect it, but simply stopped it from going forward, absorbing the energy of its thrust without impairing the energy of its twist, would not the wave then become a particle—electron or positron, according to its direction of twist, when stopped? Such particles would seem to differ from the waves from which they originated (and into which, when the circumstances were reversed they could return) only in this: that a twist which loses its forward thrust must continue its twisting and become a stationary spinning particle; while conversely a twist that acquired a thrust must spend itself by *inducing* a counter twist or twist-thrust directly in front of where it was, and so become an advancing wave.

AIR "FLIVVERS"

By Dr. EDWIN G. DEXTER

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THE question of cheap airplanes to meet a presumed popular demand has come prominently to the front, and a committee made up of outstanding leaders in American aeronautics, appointed at the authorization of the Secretary of Commerce, has met to study the problem of developing a $700 volume-produced airplane for private use—in other words, to place on the market an air "flivver." There is no reason seriously to doubt that under modern methods of mass production, it can be done, nor that in the no distant future, small but dependable planes can be bought at the price of the cheaper grades of automobile. But will there be a market for them?

Some time ago, the following appeared as an editorial in one of the leading papers of the country:

THE CITIZEN AND THE AIRPLANE

The failure of the public to patronize the airplane industry is no longer concealed. Americans are not becoming pilots in numbers sufficient to warrant the expectation that there will be a profitable business in selling airplanes to individuals for private use. Manufacturers have clung to the notion that the public would take up flying and thus create an industry comparable to the automobile industry; but in spite of reduction of prices and some improvement in the direction of safety, airplanes are a drug on the market.

The fact that Henry Ford explored the possibility of developing a market for small and cheap airplanes for private use, and did not find prospects worth while, is pretty good evidence that no such potential market exists at present.

Comment of a similar nature is more or less general.

What are the facts in support of such a contention?

Bleriot flew the English Channel in 1909—nearly twenty-five years ago. During the world war planes were doing about everything they do to-day except long-distance flying. In 1919 Alcock and Brown made a non-stop flight from Newfoundland to Ireland at a speed which has been but slightly exceeded since, and in the same year our Navy sent a plane across the Atlantic. That was nearly fifteen years ago. To-day transatlantic flights hardly make the front page. It takes a round-the-world journey or its equivalent in distance for a non-stop refueling flight to get headlines there.

More than one hundred and fifty round-trip flights are now being made daily by our commercial air lines within the continental United States with a daily average of 136,319 miles flown and carrying some 2,000 passengers at what would seem to be an almost negligible hazard. Mechanically the airplane has arrived, and no inconsiderable number of people are using it as a means of transportation. But the "flivver" is quite a different story. There seems to be little or no evidence that flying has taken any hold on the popular fancy as a means of diversion, or that planes are being generally used for other than utilitarian ends. Let us see.

The November 15, 1933, bulletin published by the Aeronautics Branch of the Department of Commerce lists 6,862 planes under the heading "Aircraft Licenses Active" and 2,314 under "Aircraft Unlicensed Active," making 9,176 heavier-than-air units—other than gliders—operable within the United States.

This does not include planes of the Army, Navy or Coast Guard.

These figures mean that there are in the country 9,176 planes used in commercial aviation or which are the property of individual owners and presumably used for pleasure I have not been able to secure data which would show with any degree of exactness the number of planes belonging to the latter class; that is, pleasure planes, but an inspection of the ownership lists prepared by the Aeronautical Chamber of Commerce of the United States would seem to indicate that one in three would be a most generous estimate. If this be so, there are in the country at the present time roughly 3,000 planes of all descriptions bought for other than business purposes, and this number may be taken as in a sense a measure of the air-mindedness of the American people, as questioned in the editorial above given.

It is true of course that the 6,000 planes used strictly for commercial purposes, as well as some thousands owned by the Army, Navy and Coast Guard, have given airplane producers their principal support up to the present time, but the demand along these lines is and will continue to be limited and the real future of aviation is determined largely by the desire or the lack of desire on the part of the people to fly as they have driven their automobiles. The automobile industry has been prosperous, not because of the half million buses and trucks produced annually but because of the millions of pleasure cars sold.

The question then is: Do the roughly 3,000 planes, owned by individuals, and used presumably for other than commercial purposes, meet a reasonable expectancy, and do they give promise of a future for aviation in any way approximating that of the automobile?

A total of less than 10,000 planes registered at the end of the fifteen-year period since the Atlantic was spanned by air, with seemingly not more than 3,000 planes bought for other than gainful purposes, can not, even by the most enthusiastic aviation fan, be interpreted as evidence of a boom. One plane to some 12,000 inhabitants or, of privately owned planes, one to each 42,000 must be anything but encouraging to the producers.

Something seems to be wrong with aviation What is it? It might be that production of planes has not kept up with demand and that potential buyers could not secure delivery But on July 1, 1930, there were listed by the Department of Commerce 217 firms which were manufacturing planes on a commercial basis. They had produced 1,684 planes during the first six months of that year, or about seven planes each I do not know how many of the firms listed in 1930 have since gone to the wall, but during the nine months from January 1 to October 1, 1933, 1,065 planes were produced, only 552 of which were listed as *civil* and *commercial*.

If, as is presumable, but one in three of these is for private use, it means that less than two hundred planes were purchased during that period for anything that might approximate "*flivver*" activities It may, I think, safely be assumed that the firms were not back on their orders and that any person with the desire for a plane and the cash to back it up could have had such desire promptly gratified.

But how about the cost? Were it not for the fact that the American people have shown a determination to have what they want, irrespective of expense, the purchase price of a plane might well be considered a distinct setback to the popularization of aviation; in the last twelve years, however, they have spent some $30,000,000,000 for passenger automobiles, $3,000,000,000 for radios and $12,000,000,000 to go to the movies. There is money for what is wanted. Even during the lean year of 1933, more than 2,000,000 automobiles, including

trucks, were purchased at a cost exceeding $1,200,000,000. If one in fifty of these cars was in the $2,500 class, and it seems to me that would be a safe assumption, it would mean 40,000 such cars purchased. But dependable planes are on the market for less than that; and in nine months 552 were bought, most of which were for commercial purposes.

No, it is not the cost of planes that is the matter; nor presumably the cost of gasoline, since a small plane will make approximately as many miles on a gallon as will an automobile of approximately the same cost. We shall have to look further for a valid alibi for our aviation boom.

But a man can not keep his plane in the garage. Perhaps there's the rub. Again let us refer to the Department of Commerce Bulletin. On November 15, 1933, there were in the country 2,172 landing fields, no state being without one or more. Of these fields 556 are designated as "municipal," 656 as "commercial," 266 as "Department of Commerce, intermediate" and 540 as "marked auxiliary"; 627 have night-lighting equipment. I do not know how many golf courses there are in the country, but it would seem to me that flying fields must be about as available as they are, and very few addicted to the ancient and royal game seem to find distance an insurmountable obstacle to its enjoyment.

Maybe the trouble is in learning to fly: Inconvenience, cost, time required, difficulty and all that. Once more our good friend, the Department of Commerce. Three years ago it listed 283 schools of aviation situated in 234 cities and towns, with no state omitted except New Mexico. No one would have to go so very far from home, and the cost for the full course, including the use of planes for the required flying time, varied from $200 to $500; the time required from two to four months. These prices and time limits do not in all instances include ground instruction, but this is not required for the pilot's license. The cost then of learning to fly is roughly equivalent to that of a semester to a full year's tuition in a first-class medical or law school and the time required from one sixteenth to one sixth of the full medical or law course. The courses do not seem to have been overcrowded, judging from the total of 14,190 licensed pilots registered on November 15, 1933. This number is, by the way, 3,549 less than in 1931. I can think of no other element in the physical aspects of the aviation problem which may have militated against its successful solution.

There are plenty of people to make a market for planes; plenty of facilities for the production of them if wanted; plenty of schools for the training of pilots; plenty of air fields and seemingly plenty of money, if we are to judge by the expenditure for autos, radios, movies, etc. Yet people have not, in any considerable numbers, bought planes. The paltry 552 planes absorbed by our civilian population in the first nine months of the twenty-fifth year since Bleriot flew the English Channel is sufficient evidence of this. With the physical aspects of the problem exhausted there is nothing left but to turn to the psychological; and here I fear we have found the solution.

Airplanes take us into a third-space dimension which since man was man has penalized the intruder. As a result there has been developed a more or less general aversion toward getting far from terra firma. Long before Wright ever saw Kitty Hawk, psychologists had recognized the fact and had given it the Greek name Acrophobia. They have, it is true, placed it in the category of abnormal mental states—and therein lies our only hope for aviation, that it *be* abnormal—but the more I study the sub-

ject the more I am convinced that the feeling is so general as to place it among the normal instinctive repugnances.

Do we read with equal horror the account of a head-on collision between two planes high in the air, and one between two automobiles, the casualties being the same in each case?

Do the same tremors creep up our spines at the thought of Jones falling downstairs and breaking his neck, that do in contemplation of Linianthal's act of jumping from his plane, a mile high over the English Channel?

Are those people who feel ill at ease while gazing down from heights like those of the Empire Building, the Woolworth Building or the topnotches of a Ferris Wheel so few as to place them in the class of abnormals? Are those who shudder at the sight of a steeplejack, or a structural worker on a beam fifty stories up, normal or abnormal? Is the classic nightmare of falling through space an indication of mental aberration? Is the person who alights from the basket of a captive balloon after a thousand feet in the air, with a profound feeling of relief to be down, abnormal? I believe not. A frank confession would probably disclose the fact that most of us have those feelings, and that the fear of the abyss is a part of our emotional make-up.

Following the general arguments of the biologists, it should be, since the fundamental principle of evolution is "safety first," and in the long run it is safer to be down than up. Their explanation would be that somewhere far back in the development of the genus Homo and fully in accordance with the law of universal variation, there were certain individuals who loved terra firma and never budged from it, and at the same time certain others, who had no such feeling, but loved to climb and proceeded to get as high as they could, up trees, crags and whatever the landscape provided. None of the former fell and broke their necks, since for them there was nothing to fall from; so they lived till the end of the chapter, breeding progeny which, like their parents, were generally not climbers. Not so with the others. The hazard of height was a fatal handicap. Some of them crashed, and after a thousand generations more or less of elimination of the climbers and the survival of the non-climbers, we have few or very few of the former left.

Every instinctive act or aversion, whether of man or the lower animals, is explained by biologists in the same manner. For example: Far back in the evolution of the cat, some individuals liked to bask in the open spaces of the landscape, while others preferred the secluded spots around the edges. No one of them had figured out any advantage in either location. This primitive feline could not hold its own in a stand-up and knock-down fight with its jungle adversary. Its safety was in concealment or flight. In this, those individuals around the edges had the distinct advantage, and in the long run, more of them survived than of the others. Since like begets like, and the survivors possessed the edge-loitering characteristic, there has evolved the instinctive aversion, manifest in all small felines, to those spots which do not provide a well-covered and instantaneous retreat, that is, the wide spaces. Probably none knew why they evade them. But let any stray tabby come along, lacking the instinct, and the chances are that it will be eliminated in short order.

So it is with all instincts—a purely fortuitous origin, so far as we know, and a progressive selection for survival of those tending in the direction of the instinct. Generation after generation, this becomes more compelling; it can not be eliminated by any process of reason and can only be inhibited by a distinct and—in human beings—usually a distressing,

fiat of will. Instincts are, so to speak, nature's life preservers. They have determined almost entirely the behavior of the lower animals and, to a considerable extent, that of man in those fields which are common to him and his ancestors There is no instinctive aversion to airplanes, since they were unknown to our forebears. There is none to high speed, such as we attain in our automobiles, since they could not by any possibility go fast enough to hurt themselves much. But they could get high enough to break their necks from falls Hence, our instinctive love of terra firma. And do not make the error of supposing that this instinct is rational or that it is based upon any conscious evaluation of the hazard involved. Instinct and reason are at the opposite extremes of behaviorism.

> I do not like you, Mr. Fell;
> The reason why I can not tell.

Nor is it fear in the ordinary sense of the word. Flying is now relatively safe, hardly more dangerous than travel by train. People are not generally deterred by the danger involved. We know it is dangerous nowadays to cross a street, yet we cross it. A perusal of the data of accidents shows that it is dangerous to go upstairs, downstairs, to take a bath or to walk across a rug. Yet we do all these things without compunction, because we know the chance of accident is small, and we are willing to gamble on it. They are all dangerous, but not sufficiently so as to deter us. The drag in aviation is not, I believe, due to its danger as based on a conscious evaluation of the hazard.

It is my belief that the future of aviation is determined not by rational but by instinctive limitation; that its field is purely one of utility; that people as a class will not fly as a diversion, and that the only persistent flyers will be those who make their living by flying and those for whom it presents a financial advantage or meets an emergency which can not be ignored. Yet if this be true, it does not by any means relegate aviation to a back seat, except in comparison with the front seat hoped for.

The railroad, the motor bus and, to a large degree, the trolley come within the above stated limitations. Nobody rides on any of them, I take it, for the fun of it, unless it be occasionally on the last. And yet all are reasonably prosperous. But aviation, in competition with any of them, must present advantages which will overcome the inherent aversion, and that is no small handicap.

The hope that aviation will in any way simulate automobiling in its development is, I fear, a futile and an idle dream. It has shown no evidence of it so far, and it has had time. If one person a day uses each registered automobile merely for pleasure, there are 23,000,000 joy-riders each twenty-four hours; and 500,000 are estimated to have flown in 365 days; and I will wager that very few of them failed to have a distinct feeling of relief when their feet touched terra firma.

A man who had "barnstormed" with a plane for months once told me that in all his experience he had had but one repeater. It is my understanding too that a considerable proportion of the return tickets on round-trip excursions by air are never presented.

But, you ask, even though we accept this thesis of an instinctive aversion to getting far from terra firma, will not the next generation, born air-wise, so to speak, have lost it? There is nothing in the development of instinct that would lead us to believe so. Traits inbred through long generations can only be bred out in the same slow manner. I have a good old dog at home which has been a member of the family for more than a dozen years. I have had no difficulty in teaching him that beds and sofas and easy chairs are no place for him. Yet I have utterly failed to teach

him not to bark at the sound of a strange footstep on the stairs. Back, nobody knows how far, his ancestors barked at unfamiliar sounds; and that is why they were his ancestors. Those which did not failed to survive, since the noise either frightened the adversary or called the pack. My dog is not afraid of what the strange footsteps mean, but he can not inhibit the bark. No animal, human or other, ever tries harder to do what is expected of him than that dog, and he frequently comes to me with evident shame at the failure of his attempts to obey and be quiet; but there is still a little yelp which it is beyond his power to repress. It had taken him thousands of generations to learn that bark, and it will not be unlearned in another. And the same is true for anything learned by the same slow process.

We are, however, safe in assuming that human beings may be more successful in inhibiting the expression of an instinct than are the lower animals. Even though our instinctive aversion to heights exists, it does not mean that nobody will fly. It would not surprise me if nearly everybody did at least once, though there is little evidence so far that this is true. We like to prove to ourselves and to others that we are brave. Then there will always be the necessary personnel to man the ships, whether they be service or commercial; but they will no more fly for the fun of it than they do now, and most of them will be looking forward to the time when they can secure ground positions, as they are now. There will always be, moreover, a group, the size of which will be determined by conditions of the commercial air service, who will fly and continue to fly more or less indefinitely because the advantages of getting somewhere by the air route are so great as to lead them to overcome the instinctive aversion by fiat of will. But the emergency must be relatively great or the fare relatively small, to make this a sizable group. It would not be strange, too, if a limited number utterly lacked the aversion which we have postulated. This would be entirely in accord with the biological principle of universal variation underlying the development of instinctive aversions. But the sad feature of such atavistic tendencies is their immediate elimination. If the aversion followed nature's "safety-first" slogan, its lack has always meant the reverse with its consequent disastrous results. If those who, like the bird, feel perfectly at home and at ease in the air and who begrudge the time spent on terra firma could live long and breed fast, we might hope eventually to develop a race of bird-men; but such persons would tend to be the Icari of modern aviation and suffer the same fate.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

SEEDS

By Dr. J. T. BUCHHOLZ
PROFESSOR OF BOTANY, UNIVERSITY OF ILLINOIS

SEEDS are the most common device for reproduction among flowering plants. They are the only means of propagation for a large number of plants, including corn, wheat and other cereals, and for many of our garden vegetables and important timber trees, such as pines. However, many plants do not have seeds, and these are dependent upon spores or other means of reproduction. Ferns, mosses, mushrooms and pond scums are reproduced by means of spores, which are tiny rounded single cells that must begin to form a new plant after they are planted. Spores also make up the powder produced by a mould or mildew. A seed is much more complex than a spore. It consists of the embryo or minute baby plant enclosed in a seed coat. This embryo is made up of many thousands of living cells and is capable of resuming growth after a long or short period of dormancy and of becoming a plant similar to the one from which it came.

Thus we find the seed to be a sort of Rip Van Winkle episode in the experience of every seed plant. For several weeks or months, the embryo develops, usually reaching a stage in which it has one or two leaves, the beginning of a root and a tiny bud. Then this tiny plant inside the seed coat goes into a period of dormancy, which may last only a few days or weeks or, in other instances, many years.

The new plant, therefore, does not begin its existence when the seed is planted, but is formed long before this in the flower of the mother plant, which always precedes the formation of the fruit. It is obvious, therefore, that the seed does not die, as some people assume, in bringing forth new life; for the new plant is already formed and exists in miniature within the seed when the latter is planted.

If a seed is dissected by removing the seed coats, the embryo plant will be found inside, and it will possess practically all the parts which may be seen in a seedling on the day after germination. Take, for example, the seed of a radish or squash This has, inside of the seed coat, an embryo plant with two seed leaves opposite each other, with a tiny bud between them, and below, the beginning of a root. The seed leaves and young root may be straight as in a squash or they may be folded and bent back on themselves within the seed coat in a great variety of ways. When this seed has germinated after planting, the two seed leaves unfold themselves and may be observed on the end of a little stalk, which is called a root, below the level where it penetrates the soil. The tiny bud, between the seed leaves, soon begins to grow rapidly and elongate into a leafy stem. Some seeds, such as the seeds of tulips and onions, have only a single slender or thread-like seed leaf with a bud placed along the side at the point where this single leaf may be considered as merging with the stem and root. While beans, radishes and squash seeds have only two parts, namely, the embryo and the seed coat, in many seeds the embryo is partially or wholly surrounded by a third part, a nutritional substance called endosperm.

It is this endosperm which furnishes

the bulk of the starchy food supply found in wheat, corn and other cereals. The endosperm serves as a sort of nurse bottle for the baby plant to last until it emerges from the seed coat. In the economy of the plant, it is the food intended for the embryo, but, alas for the new baby plant, it is also a source of food for animals and man. Aside from the foods obtained from potatoes and certain vegetables and roots, the large bulk of our starchy food supply comes from seeds, mostly from the endosperm, the food supply of the wee plant stored within the seed.

All seeds have endosperm in the early stages of development, just after the flower parts drop off In the seeds of some plants a part of the endosperm remains much longer than this, but in others it is entirely consumed by the embryo before the seed is shed from the mother plant.

Whether the food is still stored in the endosperm of a ripe seed or has been consumed by the baby plant so that it is stored a second time within the embryo itself, as in the peanut, bean or walnut, this food supply does not spoil but is available as food for animal life. Thus we find that often the embryo stores its food in the form of oil or fat, the most concentrated form in which food may be stored. The Brazil nut is so oily that one may expose the interior at one end and burn it as a candle. Of course the embryo of a seed is also a source for protein foods. It is a well-known fact that beans and other legumes are one of our most economical or cheapest sources of protein food.

Although the seed coat is the dead part of the seed, it furnishes a very important protective covering for the embryo. It protects the embryo from excessive drying and mechanical injury, and keeps out disease germs. However, the seed coat admits abundant water and oxygen when the seed is planted. Most seeds may remain dormant within their seed coats for a number of years. Although all the mythical legends that viable seeds of wheat were obtained from the tombs and pyramids of Egypt have been disproved, the seeds of some plants have been known to remain dormant for more than a century and germinate very promptly when planted under suitable conditions. Thus a seed is a wonderful device, which may preserve a plant in a dormant condition over a long period of time.

Many so-called seeds are not naked seeds but are in reality fruits. The term fruit to the botanist does not necessarily refer to an edible part accompanying or bearing seeds. The fruit is usually that part of a flower which matures along with the seed, and often the fruit appears as nothing more than an extra layer or two surrounding the seed coat. A fruit may contain many seeds or only a single seed; it may split open to shed the seeds or it may remain closed and invest the true seed permanently with an extra protective layer. Sunflower seeds, acorns and other nuts, ranging in size from the small caraway seed to the coconut, are dry fruits not easily separated from the seed which they enclose. Naked seeds are illustrated by the poppy seed, the seeds of pine trees, of radishes, peas, beans, larkspur and cotton. The fibers of cotton are outgrowths of the surface of the seed coat and here the cotton boll is the fruit.

In size, seeds and one-seeded fruits range from the tiny orchid seeds, so small that many thousands of them would be required to weigh a gram, to the large double coconut or sea coconut, growing on the palms of the Seychelle Islands of the Indian Ocean. The latter, which may reach a weight of forty pounds, require about ten years to mature, from blossom to fruit. In addition to this, they require years to germinate when planted.

Fleshy fruits which do not split open usually shed their seeds in one way or another, though this may not happen before the fruit decays. Thus the melon contains hundreds of seeds, the persimmon and apple about a half dozen and the plum and cherry only one, from which the fleshy parts are eaten by man or beast, incidentally scattering the seeds widely. Many seeds which are eaten by animals have hard seed coats and, though they pass through the digestive tract without being digested, they remain viable and germinate afterward. This is an important means for the dispersal of these seeds and explains the mystery of how certain seeds are scattered widely by birds and migrating animals and why a pasture may become filled with strange weeds.

The mechanical methods of seed dispersal are so well known that we need mention only a few. Ocean currents carry coconuts from island to island They also carry many other floating seeds whose covering is such that they are uninjured by salt water. Many seeds are small and carried by the wind, or they may be equipped with tufts of cotton or hairs such as are found on the seed of the milkweed or the common dandelion which afford small parachutes and help to carry them long distances in a gentle breeze. Even the squirrel contributes to the distribution of seeds when it hides its winter's supply of nuts and thus plants some of them in favorable situations. Some seeds or fruits adhere to the fur of animals and are distributed in this manner, while some heavier seeds are thrown out of the ripening seed capsule which springs open when the fruit is ripe. The seeds of some grasses and sedges are small enough to be carried on the feet of migrating water birds. For example, seeds of some of the rushes found at the water's edge are so tiny that there are about 70,000 to the gram. Other seeds, such as those of sedges, have air chambers which enable them to float on the surface of water and are distributed by wind and currents along the shores of lakes and rivers.

The story of the germination and development of seeds and seedlings is more or less familiar to every one who has planted and cared for a garden or window box. Sometimes people do not remember that the mechanism of reproduction has done its work within the flower which preceded the formation of the seed and that the new plant is already formed within the seed, ready to resume growth under favorable conditions, which we often help to provide when seeds are planted. However, in the economy of the plant itself the seed not only serves as a means of tiding over a long or short unfavorable period, but also as a means of multiplying the species many fold and of establishing a particular kind of plant in an infinite variety of new situations. Some plants which reproduce by seeds are so prolific that a single plant, as for example one of the wormwoods, has been known to bear over a million seeds. The jimson-weed is not unusually prolific, yet if all the seeds of a jimson-weed should germinate in a favorable place, a single plant one year could give rise to 15,000 plants in the next year. If these plants were properly spaced and each could again produce 15,000 seeds, it would require only 4 years to provide 500 times as many seeds as would be required to populate the entire earth's surface with jimson-weeds.

Thus perhaps one of the most remarkable things about seeds is the high yield possible per plant by which many species would be enabled to become world wide if they had an effective method of dispersal and were not the source of so great a part of our food supply.

THE INVISIBLE FRONTIER—OR FIVE MILES UNDERGROUND

By Dr. W. T. THOM
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BUT a single major frontier remains for the adventurous youth of to-day to penetrate and explore. The Old World and the New World are both known. The days of Daniel Boone and of Buffalo Bill are now but memories. The North Pole and the South Pole have both been reached, and darkest Africa is no longer a continent of mystery. Where, then, lie roads to a new El Dorado—to a land of new discoveries, and to a realm affording opportunities for men to prove their physical vigor, resourcefulness, skill and perseverance? Our new frontier lies beneath our feet, and our new quest is to learn what is within the earth as well as on it.

For many centuries people speculated as to what the realm of Pluto was like, or just how far down one had to dig to be in danger of a sudden plunge into the fires of hell. Such speculations were, however, without particularly important consequences, so far as can now be discovered.

Many of us have doubtless thought of what great depths had been reached when, a short time ago, oil operators actually drilled to more than two miles beneath the earth's surface, or when gold miners in South Africa penetrated for more than a mile and a half downward, but these depths shrink into insignificance when we compare the two miles thus penetrated, with the four thousand miles yet intervening between the bottom of the world's deepest oil well and the earth's center.

Geologists have indirectly penetrated deeper than the miner, and from the forms and relationships of surface features have deduced much as to the structure and constitution of the earth to a depth of about five miles. And now by a blending of geology and physics—developed partly from sound-ranging methods used for locating enemy cannon during the world war—we are engaged in a new campaign of underground exploration of what exists in the earth's sub-crustal mass, which will be at once scientifically important, educationally useful and practically worth while.

Why will such exploration be worth while? It will be worth while partly because it will add to the store of human knowledge; partly because it will give many red-blooded young men absorbingly interesting and satisfying work; and partly because it will in the course of time provide us all with a new knowledge of factors controlling the formation and place of concentration of ores as yet undiscovered, which civilization must have ere many decades, if it is to continue to supply itself with essential metals and mineral substances.

What methods of attack will be used in carrying out this exploration? Sub-crustal exploration will be carried out partly by the use of airplane photographs taken at great height, which reveal significant geological relationships invisible to one standing on the ground; partly by use of geological methods, which deduce from surface outcrops or from oil well or mine data what underground conditions are; and more and more by use of the so-called geophysical methods, which can be made to reveal underground conditions by careful studies of variations either in the local force of gravity; in earth conductivity of electricity; in earth conductivity of earthquake or explosion vibrations; or in the intensity of local magnetic fields.

By geologic interpretation of results thus obtained by applying physicists' methods and instruments to earth study, it is becoming possible for a geologist to learn of the earth's composition and anatomy, very much as an x-ray specialist now learns of the anatomy of one of his patients. True, the new geophysical arts are not yet fully developed, and their costs are yet high, but when one pauses to recall that by these methods it is now often possible to say that there is quite certainly a concealed oil structure beneath a particular square mile of a featureless alluvial plain hundreds of square miles in extent; or that a salt dome giving promise of oil and sulfur production exists beneath a particular lake, so many miles offshore in a given direction, and at a depth of so many feet; or that the thickness of sedimentary rocks filling a great trough-like downfold in the crystalline basement amounts to almost exactly 22,400 feet—we can realize what great progress has already been made in developing methods for penetrating the invisible depths of the earth.

What is the present state of our knowledge regarding earth composition? We know that many parts of the earth's surface are covered by a veneer of from a few feet to perhaps ten miles of layered sedimentary rock—most of which has been laid down in shallow sea water. We know that this outer film of sedimentary material rests on a basement of granite or of other crystalline rock formed either by the solidification of once-molten material or by the deformation and recrystallization of remotely ancient sediments. And we know that the earth apparently consists of a number of thick layers of rock, arranged much as are the layered coats of an onion, and that the rock materials composing these successive layers are progressively heavier and denser as the center of the earth is approached—the innermost core or centrosphere of the earth, some 1,500 miles in radius, being apparently composed of molten matter having the density of a nickel-iron alloy.

The best method of discovering the kind of material constituting the various shells of the earth is based on study of the speeds of the elastic waves made by artificial and natural earthquakes. From those speeds thickness of each shell can be measured with considerable accuracy. But to deduce the nature of the materials additional information is needed. We need to know how elastic are the principal kinds of rocks at the high pressures and temperatures prevailing in the earth's depths. This means special investigation of all the standard types of rocks when subjected to high pressure and high temperature simultaneously. Such a kind of research demands high technical skill. Further, any good deduction of the temperature of the earth's deep interior from the records of thermometers in mines and bore-holes similarly demands many laboratory experiments on the thermal conductivity of rocks at high pressure and temperature simultaneously—again no easy problem, but one being solved with modern methods. These and other fundamental experiments bearing on the subject are being carried on at the Carnegie Geophysical Laboratory at Washington and also under the direction of Professor Bridgman at Harvard University.

Other groups of workers in all continents have also been approaching the problem from another direction and have been seeking to advance, step by step, from the known surface of the ground to the unknown depths of the earth's interior, testing, proving and consolidating each gain in knowledge as it is made. And it is through a study of mountain structure and of how mountains grow that these other groups expect to learn definitely and accurately in

the relatively near future of the composition, properties and behavior of the outer, relatively strong and relatively brittle rocks of the earth's "crust," a "crust" which probably varies between ten and a hundred miles in thickness.

Geologic knowledge long ago progressed far enough to show that our world is far from being the *terra firma*, or stable earth, imagined by the ancients. A brief review of the geologic record shows that again and again mountain ranges and systems have been born, have grown to maturity and have then been gradually worn away by erosional processes. It is possible to point to featureless plains, in the outcrops of which the roots of primeval mountain ranges are visible; we can examine the old Appalachians which have almost wasted away under the attack of atmospheric agencies; we can study the more lofty and middle-aged Rocky Mountains, and can explore the still younger Alpine, Himalayan and Andean chains which are yet in the full stature of early maturity. Or we can watch the course of events in the great volcanic and earthquake belts girdling the Pacific, traversing part of the Mediterranean and circling the West Indian arc, in which infant mountain ranges are even now being born or are attaining their early growth.

In order that mountains may be formed, the outer film of the earth's surface—perhaps 5 to 20 miles thick, perhaps 50 to 100 miles thick—must be capable of sliding horizontally relative to points in the layers beneath. By determining the nature and amount of such relative sliding, it will be possible to ascertain not only how thick the moving film or veneer is, but also the mechanics of the movement, and, by induction, the nature of the forces which could possibly be productive of such deformations at periodic intervals.

Two lines of attack upon the secrets of mountain growth—and thus ultimately upon the problems of earth structure and constitution—give promise of being mutually supporting and highly successful.

One consists of a study of gravity conditions and bottom configuration in those parts of the oceans in which active mountain building is now in progress, for there the geometry of the growing sub-oceanic ranges can be ascertained free from modification by rain and stream erosion. Dr. F. E. Vening-Meinesz, of Holland, has pioneered in this study of sub-oceanic gravity conditions, in cooperation with the navies of the Netherlands, of Great Britain and of the United States—partly also with support from the Carnegie Institution and from the International Expedition to the West Indies recently sponsored by Princeton. And both government navies and surveys and merchant ships are supporting his work by making important contributions to our knowledge of the configuration of the sub-oceanic floor.

The second line of attack is advancing in the Alps and Scottish Highlands, in the Appalachians and Rockies, in the California Coast Range, in Japan and the East Indies, and in many other regions where erosional planation and canyon cutting make it possible to learn of the internal structure and deformational pattern of typical mountain ranges. Surface exposures in these regions make it possible to begin the reconstruction of the size, form and interrelationship of the individual uplifts composing a given mountain system, and underground evidence afforded by mines and oil wells will amplify this reconstruction and will in turn be further supplemented by the gravity studies of geodetic surveys and by other geophysical studies by oil and mining companies or by research organizations. Such researches will prospectively actually carry our pioneer study to "the

roots of the mountains," thus making possible the completion of a first main stage in our underground exploration.

How long a time this and subsequent exploratory stages will require no one can tell. What discoveries will be made either of new exploratory methods or of hidden oil and ore deposits, no one can guess We know, however, that no such study has ever yet been made without important scientific, educational and commercial discoveries resulting therefrom; and, furthermore, we know of no other line of endeavor which holds out greater hope for adventure to those who would have joined in pioneering our American frontier had they been born a hundred years ago, but who arrived too late to take part in that epic of exploration and adventure.

NO ONE NEED HAVE SCARLET FEVER

By Dr. GLADYS H. DICK
THE JOHN MCCORMICK INSTITUTE, CHICAGO

THIS talk concerns the possibility and the method of educating the body to protect itself against scarlet fever. No one need die of scarlet fever. No one need have scarlet fever. These statements sum up the results of two hundred and fifty years of intensive research on one of the oldest and one of the most dreaded diseases. The results are now available for protection of your children and of yourself against scarlet fever. The necessary materials can be obtained at your drug store, and your doctor can administer them.

Scarlet fever is caused by a minute microbe which can be seen only through a powerful microscope. Under the microscope, it looks like a minute chain of beads. The particular microbe which causes scarlet fever is characterized by its ability to manufacture strong poison. It is this poison manufactured by the scarlet fever germ which produces the symptoms peculiar to scarlet fever. And it is the discovery of the scarlet fever poison that has furnished us with the means of curing and preventing the disease.

Around a person who is suffering with scarlet fever, the air is contaminated with the patient's breath which carries minute droplets of moisture from the lungs, nose and throat of the patient. These droplets of moisture contain the scarlet fever microbes. They are so small and light that they float in the air for some time and may be carried to remote parts of the room by draughts.

If this contaminated air is breathed in by a well person, the microbe may lodge on the mucous membrane of the throat and nose. If the person who has thus become infected with scarlet fever germs has already had the disease, he usually remains well because his body has learned to protect itself. But so long as the scarlet fever microbes remain in his nose and throat, it is possible for him to pass them on to some one else without being sick himself. Such a person is known as a "carrier" of scarlet fever.

If the person who has breathed in the contaminated air has never had scarlet fever in any form, the microbes may grow in his throat and nose, producing the first symptom of scarlet fever, which is sore throat. Then as they grow in the throat, they manufacture their poison which is absorbed into the blood and carried to all parts of the body. Absorption of this poison causes the next symptoms of scarlet fever, nausea and vomiting. It also causes the scarlet red rash

which gives the disease its name. This rash usually begins to appear on the second day of illness, coming first on the chest and abdomen and spreading over the whole body, except the face. When fully developed, it consists of minute bright-red pin-point spots on a flushed skin.

If sore throat, vomiting, fever and rash exhausted the possibilities of scarlet fever, the disease would not cause much concern. In some cases, the patient grows rapidly worse and dies within a few days In others the attack may be mild. But even the mildest attack of scarlet fever may be followed or accompanied by complications which may cause death or permanent disability. These complications most frequently involve the ears, kidneys and heart.

If the scarlet fever patient recovers from the disease, he does so because his body manufactures an antidote for the poison of the scarlet fever microbe. This antidote is known as scarlet fever antitoxin. If the body does not manufacture the antitoxin soon enough and in large enough quantities, the patient dies within a few days. But this antidote can now be manufactured artificially, so that it is no longer necessary to take a chance on the patient manufacturing his own. He can be given the artificially prepared antitoxin. If the scarlet fever antitoxin is given early enough and in large enough dosage, it cuts short the course of the disease and reduces the chances of complications.

However, the only sure way to prevent complications is to prevent the disease. This is possible. It is done by educating the body to protect itself against the scarlet fever germ through teaching it to manufacture the scarlet fever antitoxin or antidote. If a person has had scarlet fever and recovered, his body usually continues to manufacture scarlet fever antitoxin indefinitely, and this protects him against other attacks of the disease. But if one has not had an attack of scarlet fever, his body has not learned to protect itself, and if nothing is done to teach it, the body does not learn this lesson until it suffers an attack of scarlet fever, and an attack of scarlet fever is always accompanied by possibility of death or complications.

We now know how to teach the body to produce the antidote for scarlet fever which will protect not only against a fatal attack of the disease itself but also against all the complications of scarlet fever and against even the milder form of the disease. This is accomplished by five hypodermic injections of small, graduated doses of the toxin which has been freed from all germs either living or dead so there is no possibility of its causing damage. These injections are given under the skin on the upper arm at intervals of one week, requiring one month for all five. They stimulate the body to produce the antidote for scarlet fever, and this antidote which circulates in the blood protects the body from an attack of scarlet fever.

Persons whose bodies have thus been taught to protect themselves may mingle with scarlet fever patients and with carriers of scarlet fever without fear of contracting the disease. The protection thus conferred is quite permanent in the majority of cases, lasting for a period of at least several years and probably much longer.

Some bodies—like some minds—do not remember all they learn. About ten out of every hundred need to take a second course a year or two after the first course. They do not usually forget after the second series of lessons.

Not every one needs to be immunized against scarlet fever. In order to learn which individuals in a given group need to be protected and which ones do not need to be immunized, a skin test is made. This consists of the injection of

a minute amount of solution between the layers of the skin on the forearm to test for the presence of the scarlet fever antidote in the blood. If the person tested has enough scarlet fever antitoxin in his blood to protect him against an attack of the disease, no pink spot will develop at the site of the skin test. Such persons do not need to be immunized against scarlet fever. If a pink spot does develop at the site of the skin test, it indicates the absence of scarlet fever antitoxin from the blood and means that person needs to be protected against scarlet fever.

Briefly outlined the new methods for controlling scarlet fever consist of: (1) A skin test to learn which persons might contract the disease on exposure to it; (2) a course of hypodermic injections to educate the tissues of the body to manufacture the antidote for scarlet fever; (3) the prompt administration of artificially prepared antitoxin to persons who are already suffering from an attack of the disease.

These methods are new, but they are not experimental. They have been extensively and successfully employed in many thousands of persons in this and in other countries during the past ten years. Their safety and their efficacy have been established by these years of experience.

SPEED AND ITS SIGNIFICANCE IN CHEMISTRY

By Dr. HUGH S. TAYLOR

PROFESSOR OF CHEMISTRY, PRINCETON UNIVERSITY

An airplane flight from Key West to Havana is approximately the same distance as one from San Francisco to Reno, but the latter is a more difficult flight. This arises from the topography of the stretches which are covered. On the one hand, there is a swift, straight course over a level sea. On the other, the plane must gain the altitude necessary to cross the intervening Rocky Mountains, an effort which taxes to capacity the energy of the machine. The speed of the transit is correspondingly decreased. In the overland flight it is not necessary, however, that the plane attain the altitude of the tallest mountain peaks. Here and there, throughout the mountainous region, are passes, any one of which the aviator may choose to reach his objective with a minimum of altitude consistent with safety. Along such highways of the Sierras the planes pass and repass.

Chemical reactions result from collisions between individual chemical units or molecules. As these units approach one another they exert forces of a repulsive nature, which oppose the tendency to react. It is the speed of the approaching molecules which overcomes these repulsions and allows the molecules to get sufficiently close to one another that the constituent atoms may exchange or rearrange to form new substances. We may think of these repulsive forces in terms of the airplane flights which we have just been considering. When the repulsive forces are small, even small velocities of collision suffice to produce reaction; the energy required is relatively little, as in the overseas flight. When the repulsive forces are great, large "energies of activation," as they are called, are required. The energy of activation in such cases may be thought of as a mountain barrier of energy which the colliding molecules must overcome. As in the case of the airplane, the molecules can find, by myriad processes of trial and error, an energy mountain

pass through which they may approach each other, with the minimum consumption of energy, to attain their final state.

It is one of the triumphs of the new mechanics applied to chemistry that it has succeeded in calculating just what is the best mode of molecular approach and how high such energy barriers are, in terms of the forces operative between the molecules, thus permitting a theoretical calculation of the speeds of some of the simpler chemical processes. It is significant that such calculations have already been able to shed new light on the subject of speed in chemical processes and to point out cases in which our experimental facts were in error. All the text-books of chemistry indicate that fluorine is an element of high reactivity. Calculation showed that this was not strictly true, and recent experiment has confirmed the results of theoretical calculation. It has been shown that the speed of such reactions is in reality influenced by the walls of the container or by minute amounts of foreign materials and that great changes in reaction speed may be effected by such influences.

The ancient alchemist hurried his chemical processes by subjecting them to heat in alembics and crucibles. Even to-day, the commonest method of speeding up reactions is by raising their temperature. Heat increases the violence of molecular collisions and so the forces of repulsion are more frequently overcome. Other forms of energy may also be used. Nature, in the springtime, illustrates not only the effect of the warmer weather but also the accelerating action of light in the lengthening days of spring. Then occurs, with marvelous rapidity, that most arresting chemical change in which, from water vapor and the carbon dioxide of the air, there comes forth the loveliness of the daffodil, the swift growth of the peony bed. The intenser forms of energy, x-rays and the penetrating rays of radium, are also familiar, even to the man in the street, who knows of their use in accelerating the destruction of malignant growths in the human body. The electric current passing through solutions, electric discharges through gases and, latterly, high-speed, electrically charged particles moving under the influence of even millions of volts, these also are means whereby speed in chemical processes may be accomplished. Out of these last experiments a new chemistry is arising, a chemistry which has for its objective the shattering even of the atoms themselves. Speed in this achievement will give to the world atomic energy.

In the meantime, we must be well content with less spectacular though still arresting successes. The first quarter of the century has seen the perfection of the use of surfaces in speeding up processes of change. The chemist found that a process which would not occur in one stage because of the height of the energy barrier could be made to occur in several stages, each of which involved much smaller energy obstacles. The analogy of the zigzag pathway up the mountain face instead of the direct assault conveys something of the idea involved. Materials ordinarily regarded as inert, as, for example, nitrogen and hydrogen, react readily on iron surfaces at temperatures for which the reaction by collision alone is vanishingly small. This surface reaction alone has had revolutionary consequences for the whole world. It permitted Germany to wage a four-year war of unprecedented magnitude when cut off from the usual sources of fixed nitrogen, the niter beds of Chile. The same reaction, too, has, in the post-war era, vastly influenced the internal economy of Chile, formerly able to sustain all government enterprises on the revenue from saltpeter export taxes. All the great nations to-day fix the nitrogen of the air by surface reactions. The increases of speed thus

attainable are enormous. A reaction studied recently in the Princeton Chemical Laboratory was found to be accelerated ten million million million fold by a copper surface, and this represents a small, rather than a high, surface efficiency The surfaces are efficient because, by reason of the unsaturation of the surface atoms, they are able to tear molecules apart into their constituent atoms, with small expenditures of energy, the atoms thus produced being able, with similar small energy effort, to rearrange to the new and desired species.

On occasion, also, the chemist can restrain the speed of chemical processes. He must do so in processes of conservation and preservation against deterioration First-quality automobile tires are now expected to give a minimum service of ten thousand miles The chemist has made that possible by finding how to compound with rubber minute amounts of chemicals which serve to arrest the normal tendency of rubber to perish The development of ethyl gasoline, in which the addition of a few thimblefuls of what was once a rare organic chemical, ethyl lead, to gallons of gasoline entirely transforms the characteristics of the fuel—this is an instance of a suppression of an undesirable knock-producing explosive reaction harmful to engine cylinders. The introduction of rust-resisting steels is yet another instance of the chemist's ability in slowing down a naturally occurring undesirable process. In many of these processes the chemical changes occur in chains started by a single initial impulse, just as in a suitably ordered array of dominoes one falling domino will overturn the rest. The added agents are, in many of these cases, inhibitors of chain reactions. Rigid pegs placed between the rows of falling dominoes would illustrate their effect.

Let us return once more to the problem of atom disruption Why is it difficult? Why is it a key problem of the future? It is difficult because of the inaccessibility of the nucleus of the atom which must be transformed. Each nucleus is surrounded by a potential energy barrier so high that heat and light are of no avail, only the swiftest moving particles, such as alpha particles or high-speed protons and neutrons, or else the most powerful energy units, such as cosmic rays, can pierce the energy barrier. Of itself, within its fortress of energy, it can not change and thus stays prisoner, save in those rare cases of the radioactive elements which spontaneously decompose. Here there is evidence that the departing fragment pierces rather than surmounts the barrier, it tunnels through just as the railroad engineer occasionally pierces the mountain rather than surmounts the surface altitude It is a key problem of the future because he who finds the solution will find simultaneously rich and inexhaustible sources of energy. The energy arises from the annihilation of matter or from its transmutation to other forms of matter simpler in structure and less in mass. It is a problem which engrosses, however, not merely by reason of its material consequences, but also by its own intrinsic difficulty and beauty. This dual aspect of nature's problems is ever the lure of the scientific investigator. Its duality is finely expressed in those lines, by the late English poet laureate, Robert Bridges, from the "Testament of Beauty"—

Science sitteth apart in her exile, attent
on her other own invisibles; and working back
to the atoms, she handleth their action to harness
the gigantic forces of eternal motion,
in serviceable obedience to man's mortal needs;
and not to be interrupted nor call'd off her task,
dreaming, amid the wonders of her sightly works
thru' her infinitesimals to arrive at last
at the unsearchable immensities of Goddes realm.

THE TELEPHONE POLE AND THE MUSHROOM

By Dr. R. H. COLLEY

OUTSIDE PLANT DEVELOPMENT, BELL TELEPHONE LABORATORIES

According to the story, Alice had been running through the woods and had paused to rest near a large mushroom. Under the dramatic conditions of the experiment the mushroom was as tall as Alice herself. It may be assumed that she did not know it was a fungus. She probably had never heard of biology. But she was in a most unique position to get a proper perspective of that particular mushroom, and she proceeded to examine it from all sides. The umbrella-like top of the mushroom possessed very special powers. She found that a little bit taken from one side of it would make her grow tall, and that a little bit from the other side would make her grow short; and that by properly balancing the amounts of each piece she could keep herself just about the right size. It is small wonder, under the circumstances, that the mushroom assumed such a large though temporary importance in Alice's eyes.

Outside of the fable such opportunities for gathering information about fungi are likely to be confined to the realms of the imagination. Formerly the evanescent fairy rings of toadstools in moonlit meadows were the arenas for the sports and games of elves and gnomes and dwarfs. Nowadays these same fairy rings form their strange circles in the grass to spoil the turf on putting greens. The fact that mushrooms appear for a time and then are gone gives them a sort of will-o'-the-wisp character. They are, however, very real.

If, for convenience, all plants be divided into two groups—those having the green coloring matter called chlorophyll, on the one hand, and those that do not have it, on the other—we may define the position of the fungi by saying that they belong to the latter group. The two groups are continually in opposition. With the aid of chlorophyll and light, and the substances found in air, water and soil, the green plants make and store up a food supply. Green plants are builders. Fungi, generally speaking, are destroyers or scavengers. Lacking chlorophyll, they are dependent for their food supply on the tissues and stored substances made by the green plants. They are often classed, therefore, either as parasites or saprophytes, depending respectively on whether they attack living plants or simply break down the non-living product of the green plants. The forms of fungi are myriad, varying all the way from minute, single-celled organisms, to giant shelf-like brackets. The latter belong in the great group which includes the mushrooms and their relatives, and it is this group which is of special interest to those concerned with outside plant.

Certain mushrooms and many forms of bracket fungi are the most important wood destroyers in the world, probably not excepting fire and man. After a tree reaches a certain age it becomes more and more susceptible to infection by such fungi. They attack any exposed sapwood, and they gain entrance to the heartwood through wounds or along old branch stubs. Once established, they proceed slowly but surely to turn the wood back into the elements from which it was created. Other fungi, usually

distinct as far as species is concerned from those that attack the wood of the living tree, are lying in wait to attack the wood of the tree as soon as it is sawed into lumber or cut and peeled for use as a pole.

Given a potential food supply, such as the sapwood of southern pine, there must be a sufficient amount of moisture present, and a sufficient amount of warmth, before the fungus can attack the wood at all; and the warmth and moisture conditions thereafter determine largely the rate of growth and the degree of destruction Of the two factors, moisture and warmth, moisture is the more important. For instance, thoroughly wet or thoroughly dry wood will not rot. There is too much moisture in the one case, and too little in the other. Cold slows down or stops fungus activity, but low temperatures rarely kill. Favorable growth temperatures range generally between 70° and 100° Fahrenheit. Higher temperatures retard the growth, and more intense heat kills the organism. Moist heat kills more quickly than dry heat.

With this background of generalities, a more specific description of the fungus life cycle may be introduced. The simplest unit in this life cycle is a single cell, or spore, that corresponds by analogy to the seed of green plants. The spore germinates, if the moisture conditions are favorable, by sending out one or more delicate germ tubes. Germination may be said to correspond to the sprouting of the seed. If germination has taken place on the ground the germ tubes lengthened out into filaments that branch and rebranch among the soil particles. Food is probably obtained by absorption from the material in solution in the soil water or by direct attack on plant debris in the soil. If a spore happens to be blown into a check in the surface of a pole, or if it is drawn into the check by capillarity, germination may take place under conditions that make it possible for the germ tube to find its way into the cells of the wood. If there is enough water in the wood, say 25 or more per cent., based on the oven dry weight of the wood, the germ tube develops into a branching system

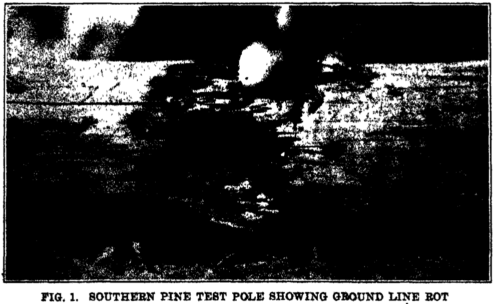


FIG. 1. SOUTHERN PINE TEST POLE SHOWING GROUND LINE ROT

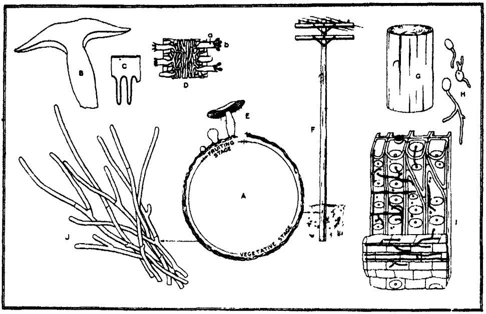


FIG. 2. MUSHROOM AND MAINTENANCE—A MURAL IN MINIATURE

A. THE LIFE CYCLE OF THE MUSHROOM IS MADE UP OF TWO ALTERNATING STAGES, AN INDEFINITE VEGETATIVE STAGE AND A RELATIVELY SHORT LIVED FRUITING STAGE IN THE COURSE OF THE CYCLE THE FUNGUS FILAMENTS (MYCELIUM) MASS TOGETHER AND FROM THE TANGLE THE FULL-SIZED MUSHROOM DEVELOPS B A LONGITUDINAL VERTICAL SECTION OF THE MUSHROOM. THIN PLATES CALLED GILLS HANG FROM THE UNDER SURFACE OF THE CAP. C. THE SURFACES OF THE GILLS ARE COVERED WITH STUBBY CELLS THAT BEAR THE SPORES. D. AN ENLARGED VIEW OF A PART OF ONE OF THE GILLS SHOWING THE SPORE-BEARING CELLS (*a*), AND THE SPORES (*b*). E, F, G. THE SPORES RIPEN ON THE GILLS AND ARE THEN CARRIED BY THE WIND TO THE GROUND OR TO SOME LIKELY RESTING PLACE SUCH AS A CHECK IN THE POLE G. THE CHECKS IN THE SURFACE OF THE POLE G SERVE AS PORTS OF ENTRANCE TO THE INNER SAPWOOD AND THE HEARTWOOD OF THE POLE. H. GERMINATING SPORES THE GERM TUBES DEVELOP INTO FILAMENTS THAT EITHER SPREAD THROUGH THE SOIL AND INTO THE BELOW-GROUND SECTION OF POLE F, OR INFECT THE UPPER PART OF THE POLE DIRECTLY THROUGH A CHECK. I. A DIAGRAMMATIC REPRESENTATION OF A MYCELIUM OF THE FUNGUS WORKING ITS WAY THROUGH THE WOOD CELLS. COMPARE FIG. 5 J. THE TIP OF AN ADVANCING MYCELIUM FAN. COMPARE FIG. 3.

of fungus filaments (mycelium). At first the growth of these filaments depends upon the reserve food material in the spore. Then, as they become longer and longer, they bore through the wood cells and begin to destroy the cell walls.

These walls are laminated structures made up of cellulose and lignin. Just how the fungus breaks down these substances is not clearly understood. It seems probable that enzymes are produced locally at the tips of the filaments and that these enzymes soften the walls so that the filaments can bore through from one cell to another. The destruction process suggests a catalysis. In the advanced stages of decay the cell structure of the wood becomes more or less completely disintegrated.

The wood in that part of a pole in contact with the ground probably becomes infected by fungus filaments that are present in the soil. Above ground

the infection appears to result from the germination of spores carried by the wind, by rain-water, by birds and animals and by insects.

All the time the fungus is in the filamentous form, and while it is actually breaking down or rotting the wood, it is said to be in the vegetative stage. After the rot has become well advanced the filaments may or may not mass together. If they do, and the moisture conditions are still favorable, a pronounced change in the behavior of the filaments takes place. They merge into a tangled mass, and instead of remaining microscopic threads, hidden away from the light, they begin to work to the outside of the pole. From the massed filaments a typical mushroom may appear overnight, to remain for a short time before it is eaten by insects, or before it dries and is blown away by the wind. Before it is destroyed, however, it produces millions of spores, a few of which may in their turn, if the conditions are right, germinate and start another revolution of the life cycle.

There is a marked difference in the

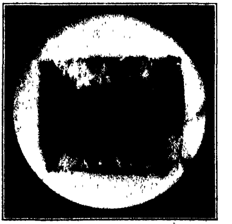


FIG. 3. IN THIS CULTURE, A WOOD-DESTROYING FUNGUS IS GROWING ON AN AGAR JELLY, ON TOP OF WHICH IS PLACED A THIN SLAB OF WOOD. THE MYCELIUM OF THE FUNGUS IS SPREADING IN FAN-LIKE WEFTS OVER THE SURFACE OF THE WOOD.

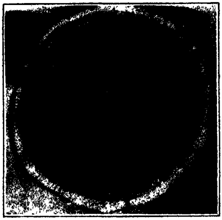


FIG. 4. LOCALIZED "PIPE ROT" IS HERE SHOWN IN THE HEARTWOOD OF A NORTHERN WHITE CEDAR POLE. SIMILAR LOCALIZED ROTS OCCUR IN CYPRESS AND REDWOOD. THEY RARELY SPREAD AFTER THE TREE IS FELLED.

virulence of wood-destroying fungi. A few appear to be omnivorous. Others are limited to certain woods. Generally speaking, the fungi that attack chestnut, or cedar, will not attack pine, and the common fungi on pine will not attack chestnut and cedar. There are exceptions to the general rule. The woods themselves vary in their natural resistance to attack. The sapwood of all species is non-durable. The heartwood, on the other hand, is relatively durable. The heartwood of the cedars is among the most durable of woods; the heartwood of chestnut ranks high for durability among the woods of broadleaf trees; and the heartwoods of southern pine and Douglas fir are fairly durable if they are kept from contact with infected sapwood.

It so happens that the cedars and chestnut have a relatively thin sapwood layer surrounding the durable heartwood. The depth of this layer in chestnut averages only about .22 inch; in western red cedar it averages approximately .65, and in northern white cedar approximately .55 inch. In Douglas fir the sapwood on pole size timber is a

little more than twice as thick as the sapwood of western cedar. Lodgepole pine sapwood has about the same thickness as Douglas fir. The sapwood of southern pine poles averages about 3.2 inches deep. It may be assumed that this sapwood is a most easily available food supply for fungi. This is another way of saying that the sapwood is soon attacked and destroyed under conditions favorable to fungus growth. Infection may take place while the poles are lying in the woods or in storage piles in yards of the pole producers. In fact, infection is so general that it may be regarded as inevitable unless certain precautions are taken. These precautions are usually aimed at con-

FIG. 5. THIS SECTION OF AN INFECTED PIECE OF SOUTHERN PINE WOOD, CUT IN A RADIAL PLANE, SHOWS THE TUBULAR WOOD CELLS THAT RAN LENGTHWISE IN THE TREE (*a*), A PATCH OF RAY CELLS (*b*) THAT RAN RADIALLY FROM PITH TO BARK, AND THE FILAMENTS OF THE ATTACKING FUNGUS (C). THE ELLIPTICAL BODIES IN THE WOOD CELLS (D) ARE BORDERED PITS, OR OPENINGS, THAT LEAD FROM ONE CELL TO ANOTHER.

trolling the moisture conditions, and that amounts to getting the water out of the sapwood as soon as it is practicable to do so. The faster the sapwood dries the less chance there is of infection; and if the wood is once dried and

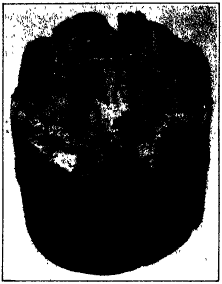


FIG. 6. CHESTNUT POLES OCCASIONALLY ROT ACROSS THE WHOLE DIAMETER. ROTS OF THIS TYPE CAN NOT BE CONTROLLED BY TREATING THE BUTTS OF THE POLES WITH CREOSOTE BECAUSE THE INFECTION WORKS FROM THE INSIDE OUT.

then kept dry it is not likely to rot, because the moisture content is too low to promote fungus growth.

All things considered, it would appear to be easier to dry out the thin sapwood of the cedars and chestnut than to dry out the sapwood of southern pine, and

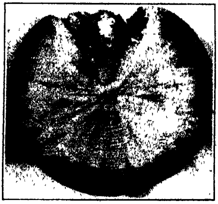


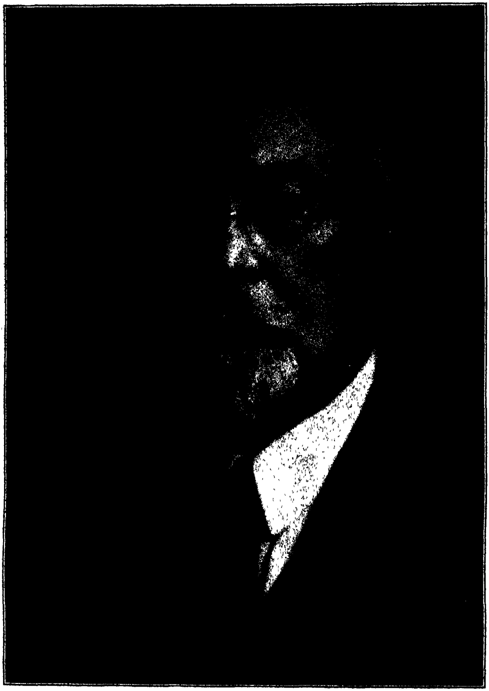
FIG. 7. THIS CROSS-SECTION OF A CREOSOTED SOUTHERN PINE POLE SHOWS DECAY OF THE UNTREATED SAPWOOD.

generally that is the case. However, if a dry pole is placed in the ground two sets of moisture conditions arise. The sapwood on the part of the pole above ground becomes alternately wet and dry, according to the weather conditions, while the sapwood on the part of the pole below the ground is kept moist by water in the soil. For a time the sapwood in the upper part of the pole may be resistant to fungus attack because of its relative dryness, but the moisture and food supply requirements of the fungus are met in almost ideal fashion in the sapwood below ground. Except when the ground is frozen or in the cold weather of spring and fall, the temperature conditions are favorable for growth The result is a fairly rapid disintegration of the moist sapwood. Obviously, the pole user, in his fight against decay, can not depend on controlling moisture content. There is only one other way to handle the situation and that is to poison the food supply. So it appears that as far as fungi are concerned a relatively simple biological fact is the basis of the wood-preserving industry, whose business it is to make wood unpalatable to fungi.

The most commonly used wood preservative is coal tar creosote. Durable woods like cedar and chestnut are butt-treated by soaking the butt ends of the poles, up to about one foot above the ground line, in creosote. Lodgepole pine for use in the relatively dry mountain states is also butt-treated because the sapwood on the part of the pole above ground does not hold enough moisture to satisfy the water requirements of wood-destroying fungi. Southern pine and Douglas fir are treated full length by impregnation with hot creosote under pressure, the purpose being to penetrate as much of the sapwood as practicable.

Such preservative treatments are absolutely necessary if the poles are to give long service in the lines, all because, in nature's scheme of things, certain non-green plants called fungi are continually tearing down the wooden products made by the activities of the cells of certain green plants called trees. Man interferes in the biological battle, but his best efforts result in merely deferring the victory by the persistent cobwebby filaments of the fungus.

Alice's adventure with the mushroom seems not so wonderful, after all.



WILLIAM MORRIS DAVIS

THE PROGRESS OF SCIENCE

WILLIAM MORRIS DAVIS, AN APPRECIATION

To but few men is it given to enjoy vigorous activity in a field of science continuously for a span of six and a half decades and to be, moreover, the outstanding and acknowledged leader in that field for a large part of that period Yet such was the enviable experience and admirable accomplishment of William Morris Davis, physiographer and geologist, whose long and rich life ended rather suddenly but peacefully at Pasadena, California, on February 5 of this year. He had not quite reached his eighty-fourth birthday

Of the scientific men of this country, Professor Davis had been for many years one of the best known, not only to workers in the geological and other sciences but also to the general public Of his voluminous writings many were couched in a style and terminology which rendered them comprehensible to the non-technical reader as well as highly instructive to the specialist

The studies of his earlier years were largely of more strictly geological nature, some of them in the tilted and eroded formations of the Connecticut Valley, and these gave an excellent foundation for his later work. The much more important and really great fundamental contributions were mainly in the physiographic field, or geomorphology, as that branch of geology has been termed in later years. It was known still earlier as physical geography. Professor Davis often considered himself a geographer, but it was not with the regional or the economic phases of geography that he was concerned, or the adaptation of man to his environment, which so largely absorbs many geographers to-day. He was interested chiefly in gaining a more precise understanding of the nature of the land forms of the earth's surface, the origin of those surface features and the later geological history which can be deciphered from them when they are carefully studied. Naturally one of the important results of his work was a fuller comprehension and appreciation of the character and origin of natural scenery.

He began his scientific career shortly after the publication of the "Origin of Species," and he more than any one else in this country urged that the evolutionary concept is as applicable to the origin of the physiographic features of the earth's surface as to the organic kingdom. According to this view, the landscapes of the globe have not always existed as we now see them, nor were they so created; instead, they are the result of evolution through a long series of orderly changes

Professor Davis' scientific papers are characterized by clarity, unusual completeness of statement, inclusion of vast detail in support of the general thesis advanced and by remarkable illustrations, in large part freehand drawings of high effectiveness executed by his own hand

Space forbids mention of all the subjects which he investigated, but among the more important were the geographic cycle or cycle of erosion, coral reefs, glacial sculpture, the ranges of the Great Basin, the influence of geologic structure on topography, marine shore terraces, river terraces, the unique land forms produced and the precise processes involved in desert erosion.

The concept of the cycle of erosion, so magnificently elaborated by him and taught to the geological profession with unabated vigor for several decades, influenced physiographic thinking profoundly. It is this concept with which

Professor Davis' name probably is linked more closely than with any other in the minds of American and European geologists and geographers. Briefly, it postulates that when a region is uplifted from low to high elevation it is attacked and dissected by streams and other erosional agencies and passes through a cycle or orderly series of systematic topographic changes whereby it is in the end again worn down to the rather flat landscape at low level which it possessed before uplift. Davis termed the successive stages in the cycle youth, maturity and old age, and described fully and with remarkable vividness the physiographic characteristics of the landscape in each stage. These characteristics, once known, can now of course be used to ascertain whether an area has been uplifted relatively recently, a somewhat longer time ago or at a date much more remote in geological time—but never very remote, since it is recognized that the whole cycle requires only a small fraction of the total length of geologic time for its completion. The landscape of a region in youth—recently uplifted—is marked by bold canyons, large areas of original pre-uplift surface as yet unmodified and undissected by the headward-growing streams which will soon invade it, high gradient and swiftness of the streams and coarseness or gravelly character of their burden, and close resemblance of the uplifted area to the form determined by the nature of the uplift, whether an upwarped arch or dome, upwarped or upfaulted plateau or tilted fault block. In maturity the whole region has been dissected to slopes, the relief within it is at a maximum, the streams have begun to widen the downstream parts of their valleys by lateral corrasion and now carry much more fine material, and all remnants of the pre-uplift topography have disappeared. In old age the region has been worn well down toward its pre-uplift elevation, the mountainous relief of maturity has melted down to one of hilly or rolling aspect, the streams are slow and wide and carry mainly clay, and deep soils, giving rounded contours to the countryside, rather than extensive rock outcrops, characterize the landscape And in very advanced old age the area becomes a "peneplain," a rather featureless "almost plain" on which the only eminences consist of residual hills of somewhat harder rock as yet not entirely reduced by the prolonged erosional process. The erosion cycle has become extremely useful to geologists in the elucidation of the later geologic history of areas under investigation and to travelers generally as an aid in understanding the landscape.

A unique feature of Professor Davis' scientific work, particularly on the erosion cycle, was the use of what he termed the deductive method This consisted first of the formulation, with the aid of facts already discovered, of an explanation or hypothesis for the particular phenomenon or problem; this explanation was often elaborately developed by logical reasoning rather than by observation. Then with the postulated explanation as a guide, not for searching for certain facts favorable to it but for pointing out the type of evidence that would be critical, further observations would be made. The explanation would then be tested by confrontation with these additional facts.

The problem of coral reefs and atolls held Professor Davis' interest for many years. Quite recently he published a book supporting strongly and elaborating the view announced by Charles Darwin that barrier reefs and atolls develop from fringing reefs through subsidence of the islands on which they rest, and setting forth fully the relation of the physiographic history of islands to the character of the reefs encircling them.

Graduating from Harvard in 1869, he served as professor from 1877 to his retirement in 1912. Beginning about 1924, he lectured at universities in Cali-

fornia, Oregon and Arizona and during the past three years was a member of the staff at the California Institute of Technology.

He was greatly interested in teaching methods and devices. A set of illustrative models he designed, depicting natural features ranging from volcanoes to glaciated peaks, were scattered widely in the schools of the United States With advanced students, especially, his enormous enthusiasm was very inspiring

Organizing scientific parties was a joy to him. In 1912 he led the Transcontinental Excursion of the American Geographical Society, in which many scholars from abroad participated. During the last decade of his life he was largely instrumental in organizing two scientific outdoor clubs in southern California—the Rift Club and the Southern California Intercollegiate Excursions.

He was the author of a number of important books, mainly in the field of physiography, in addition to the large number of shorter scientific contributions in the journals. Great interest in the application of scientific knowledge to the betterment of society led to the publication of several introspective essays bearing on sociology and ethics.

He had traveled extensively in practically all the continents and was at different times exchange or visiting professor at several of the great seats of learning in Europe.

To the end of his life his lectures, both popular and technical, delighted his hearers. The illustrated lecture on the Grand Canyon, delivered before audiences in all parts of the United States, became virtually a classic and was enjoyed by thousands of persons

Born of Quaker ancestry, Professor Davis made the world in which he spent his life a better place for humanity—scientifically, socially, morally.

John P. Buwalda,
Chairman, Division of Geology and Paleontology
California Institute of Technology

THE AWARD OF THE WILLARD GIBBS MEDAL TO DR. UREY

For his discovery of "heavy water," which promises to rank among the great achievements of science, Dr. Harold Clayton Urey, of Columbia University, has been awarded the Willard Gibbs Medal of the Chicago Section of the American Chemical Society.

Dr. Urey was born in Walkerton, Ind., on April 29, 1893, the son of Samuel Clayton Urey and Cora Rebecca Reinoehl. His father, who was a minister and a high-school teacher, died when he was six years of age, leaving also a younger brother and a sister. The widow, in spite of severe financial handicaps, was determined that her son should receive an education, and it is due to her heroic efforts and the later help of his step-father, M. A. Long, that he received a college education.

The medalist's summers were spent working on the farm until he was eighteen years of age During the winter he attended the Walkerton and Kendallville, Ind., high schools. In 1911 the family moved to Montana, and after teaching country school for three years, he entered the State University of Montana at Missoula, receiving in 1917 the B.S. degree in zoology. During the war he was employed as a chemist with the Barrett Company at Philadelphia.

Following two years' service as instructor in chemistry at Montana, he adopted Horace Greeley's advice and migrated to the University of California at Berkeley, where he came under the inspiring influence of G. N. Lewis. He was assigned the problem of verifying experimentally the predictions of the Sackur-Tetrode equation applied to the thermal ionization of cesium vapor, but

Oesip Garber Studio.

DR. HAROLD CLAYTON UREY

did not succeed in this objective. Fortunately this problem focused his attention on Bohr's theory of atomic structure, which at that time had not been sufficiently appreciated by chemists in this country. He presented a theoretical thesis on the calculation of the heat capacities and entropies of gases. This appears to have been the first application in this country of the accurate data obtained from band spectra to fundamental thermodynamic problems. The science of statistical mechanics is indebted to Professor Urey for his courage in breaking new ground in a field which has since developed into an important chapter of modern physical chemistry.

Professor Urey's interest in atomic structure received encouragement by the award of the American Scandinavian Foundation Fellowship for study at Copenhagen under Niels Bohr. The year 1923–24 was a most fortunate time to be in Bohr's laboratory. It was one of those periods in the history of atomic physics when the attack upon an apparently simple problem uncovered fundamental problems more rapidly than they

could be solved, when the problems themselves often proved to be incapable of solution by the means then available, a time when even the first law of thermodynamics seemed of doubtful validity in the light of the observed phenomena He had the good fortune to be associated in these enterprises with a number of young men who were then making lasting international reputations in physics, among others, H A Kramers, Werner Heisenberg, W. Pauli and J C Slater.

His training as a chemist at California and his experience in physics at Copenhagen determined his present work in the border line between chemistry and physics, as is evidenced by his editorship of the *Journal of Chemical Physics* and many publications culminating in the treatise published in 1930 with Professor A E. Ruark and entitled, "Atoms, Molecules and Quanta." This book has become an outstanding work on atomic and molecular structure in English.

On returning from Copenhagen he was appointed associate in chemistry at the Johns Hopkins University, and in February, 1929, he joined the department of chemistry of Columbia University for the purpose of developing the fields of atomic and molecular structure

One of Professor Urey's distinguishing characteristics is his interest in somewhat unorthodox researches His greatest pleasure comes in attempting problems which often have the hazard of giving negative conclusions but which at the same time hold out the possibility of giving novel results The year 1930–31 was thus spent in an unsuccessful attempt to separate the isotopes of chlorine by photochemical means. Early in

EDWARD WIGHT WASHBURN

CHIEF CHEMIST OF THE NATIONAL BUREAU OF STANDARDS UNTIL HIS DEATH ON FEBRUARY 6.

the summer of 1931, Professor Urey became convinced on several grounds that an isotope of hydrogen of mass two should exist, and that it should be possible to prove its existence if proper precautions were taken in producing and photographing the spectrum of the hydrogen discharge tube Here was a problem that certainly appeared to be destined for negative results, as this spectrum had been carefully studied by many investigators. Through the cooperation of Dr. Brickwedde, of the cryogenic laboratory of the Bureau of Standards, samples of liquid hydrogen, which had been redistilled under conditions suspected on well-founded principles of favoring the concentration of the heavy isotope, were tested in the discharge tube with the assistance of Dr G. M. Murphy. The essential precaution taken was that of accentuating the atomic spectrum and depressing the molecular spectrum by the addition of water vapor, which effectively prevents the recombination of hydrogen atoms on the walls of the tube. This time the goddess of good fortune favored the research, but the favor was overdue and well deserved. The discovery was made possible only as a result of intelligent planning based upon sound theoretical principles.

Dr. Urey early suggested to the writer and his colleagues the possibility of separating the isotope by electrolysis, but in view of the numerous failures in the case of other elements and the lack at that time of any plausible theoretical reason for success, we had to forego the experiments in favor of the method of gaseous diffusion, which had yielded encouraging results through the partial separations of the isotopes of other elements. Shortly thereafter Dr. E. W. Washburn, of the Bureau of Standards, submitted for spectroscopic analysis samples of water exhibiting densities greater than normal which he had prepared by electrolysis

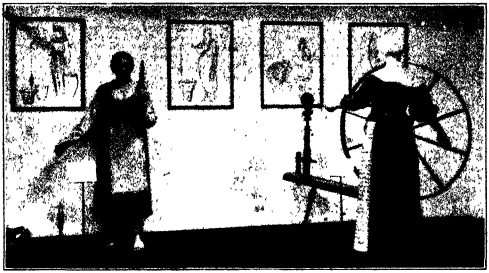
It is a matter of deepest regret that Dr. Washburn's untimely death on February 6, at the age of 52 years, occurred before he had received the recognition which he so richly deserved for discovering the remarkably effective electrolytic method of preparing "heavy water," the more so when it is recognized that he prosecuted his researches not only in the face of declining health, which was both rapid and certain, but also in spite of drastic and discouraging reductions in the budgets of the scientific bureaus of the government for work of this character.

Urey's discovery of the element and Washburn's method of separation have revolutionized the research programs of many laboratories in chemistry, physics and biology. The reason is quite evident. Hydrogen as the constituent of water and in the form of numerous carbon hydrogen compounds is the element most frequently encountered by the chemist and biologist. The physicist is intensely interested in the use of the deuterium nucleus, or so-called deuton, since he has found that it has remarkable properties as a projectile for producing transmutations of elements and particularly for the production of neutrons.

VICTOR K. LAMER

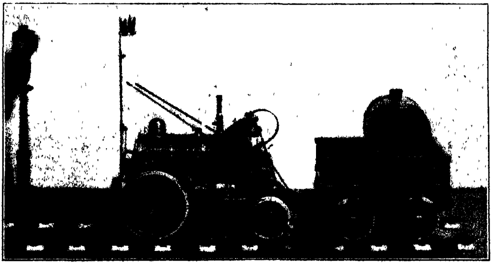
STATISTICAL CHARTS REGARDING EMPLOYMENT EXHIBITED AT THE NEW YORK MUSEUM OF SCIENCE AND INDUSTRY

ANY approach to a statistical study of the relation of science and inventions to employment should from the start recognize two aspects of the situation—one, the influence of those scientific discoveries and practical inventions that have created new industries or new services, and the other, those inventions that have

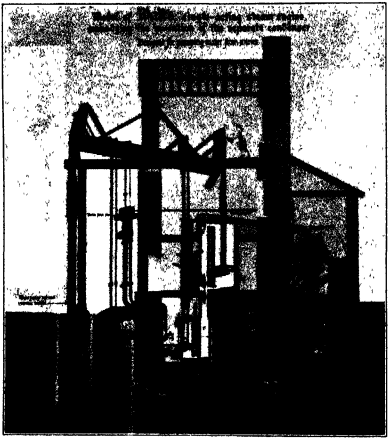


SPINNING WITH A BOBBIN AND WITH A HIGH WHEEL
THESE TWO FIGURES ILLUSTRATE THE FIRST METHODS OF INTERMITTENT SPINNING WHICH FOUND ITS CULMINATION IN THE POWER DRIVEN SPINNING MULE.

improved or expedited processes of production. The first have created the modern age and given employment to untold millions of workers. In some cases the increases in employment can be plotted. The second may or may not result in reduction of the number of workers employed. In certain cases resultant reduction of workers can be plotted, but the secondary effects of such improvements in machines and methods, while they may be of greater social significance



THE "ROCKET"
THIS LOCOMOTIVE, BUILT BY ROBERT STEPHENSON & COMPANY FOR THE LIVERPOOL & MANCHESTER RAILWAY IN 1829, WAS THE FIRST TO INCORPORATE SEVERAL FUNDAMENTALS OF MODERN DESIGN: HORIZONTAL, MULTIPLE FIRE TUBE BOILER WITH WATER JACKETED FIRE BOX; USE OF EXHAUST STEAM IN SMOKE STACK TO PRODUCE FORCED DRAFT; PISTONS DIRECTLY CONNECTED TO DRIVING WHEELS BY CRANK AND CONNECTING ROD.



OPERATING MODEL SHOWING PRINCIPLES OF WATT'S CONDENSING ENGINE
THE ENGINE REPRESENTED WAS BUILT IN 1788 AND WAS DESIGNED FOR PUMPING WATER FROM MINES. THE OPERATION OF THE MUSEUM MODEL SERVES TO CONTRAST THE SEPARATE CONDENSER OF WATT WITH THE CYLINDER CONDENSATION OF THE EARLIER NEWCOMEN ENGINE MODEL AT ONE SIDE

than the reduction in numbers employed, are difficult to set forth and to weight as to relative values

One common effect of the introduction of labor-saving machinery is to reduce the price of the article produced or the service furnished, an effect that often reacts broadly upon large numbers of consumers. Another effect often resulting is increased efficiency in the product or service, which also results in increased consumption and constitutes an economic and social gain to consumers at large

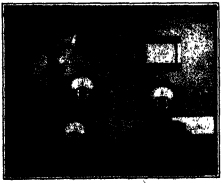
With certain comparatively recent inventions based on important scientific discoveries which have resulted in new services utilized by millions of people, such as the telephone, radio and motion pictures, convincing statistical presentations are comparatively simple, inasmuch as they have produced, either wholly or in large part, entirely new opportunities for employment. In other cases it is possible to contrast the numbers employed to-day with those engaged in the corresponding industries that have been replaced.

In still other cases difficulties of statistical presentation are far greater. With great industries and services, such as automobile production, distribution and

maintenance, steel ship-building and railroad equipment and operation, which utilize the products of many contributing industries, the problem of statistical presentation is infinitely more complex.

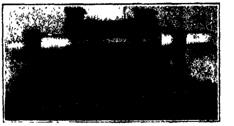
The charts developed by the New York Museum of Science and Industry relate to the following scientific discoveries and inventions: the cotton gin, the rayon process, mechanical refrigeration, the incandescent lamp, the various inventions that gave us the modern automobile, the steam locomotive, air brake and signaling apparatus—essentials in modern steam railroad development—the marine engine, propeller and steel ship fabrication—fundamental to modern shipping—the airplane, the telephone, radio, motion pictures, the discoveries of Faraday and other scientists which underlie the development of the electrical industry.

A case typical of fairly sound opportunities of comparison between the numbers employed in a replaced industry and those employed in the present situation, and also one involving the element of unknown numbers of persons employed in contributing industries, is furnished by automobile production, operation, maintenance and distribution. This case was presented as follows



DEMONSTRATION OF THE FARADAY EXPERIMENT

THIS EXHIBIT BRINGS OUT THE MEANING OF FARADAY'S CLASSICAL EXPERIMENT AS THE BASIS FOR THE DEVELOPMENT OF THE ELECTRICAL GENERATOR.



WILKINSON'S BORING MILL

A REPRODUCTION OF JOHN WILKINSON'S BORING MILL. THE ORIGINAL WAS BUILT ABOUT 1775 AND MADE POSSIBLE THE CONSTRUCTION OF WATT'S STEAM ENGINE BY PROVIDING A MEANS FOR BORING THE STEAM CYLINDERS.

Science and Inventions that Create New Industries and New Services Make More Jobs

Automobile Industry

The inventions that have made the automobile possible were responsible for the direct employment in production, distribution and operation of 2,409,394 persons in 1930, without counting those employed in contributing industries such as steel, rubber, glass and textiles. These figures may be compared with the number (976,004) engaged in the production of horse-drawn vehicles and in their operation and care in 1900.

Similar to the case of the automobile industry is that of the railroads, which employed 1,798,171 persons in 1930 in manufacture, including air brakes and signals, construction, administration, operation and maintenance, as compared to 68,173 persons employed in 1850 in the carriage and wagon industry, including drivers, livery stable keepers, saddle and harness makers, drivers and teamsters. This figure, when corrected to correspond to the increased population in 1930, becomes 360,307.

Somewhat similar conditions are presented by steel ship-building, which is largely an assembling industry. Because of this fact it is very difficult to make comparisons with employment in the days of wooden ships.

CARRIAGE AND WAGON INDUSTRY, 1900*

	No. persons employed
In carriage and wagon factories	73,812
In harness and saddle factories	40,193
Carriage drivers, teamsters, draymen	541,115
Livery stable managers and assistants	36,918
Hostlers and stable hands	65,381
Blacksmiths	218,585
	976,004†
† This figure, corrected to correspond to the increased population in 1930, gives	1,572,928

AUTOMOBILE INDUSTRY, 1930*

	No. persons employed
In motor vehicle factories	253,228
In body and part factories	241,813
In tire and tube factories	96,249
Chauffeurs and drivers	972,418
In filling stations	150,521
In garages, repair and parking	120,129
In truck, transfer and cab companies	82,045
Bus conductors	1,002
Dealers, wholesale and retail	491,989
	2,409,394

* U. S. Census, 1900, 1930—Report for Occupations.

In only one instance, the manufacture of incandescent lamps, was it found possible in the time available for the development of the museum's legends to present statistically what have been referred to above as the secondary effects of inventions aiming at improvements in production processes and the reduction of labor.

Incandescent Lamps

The history of incandescent lamp production shows strikingly that statistics of employment do not reveal all the social implications of an industry. In 1920 about 26,000 persons were employed in the production, development and wholesale distribution of incandescent lamps. At that time approximately 322,000,000 lamps were produced and the average price was 34 cents. For the next ten years continuous improvements in methods of manufacture increased the efficiency of the lamp and reduced the number of employes to 15,000 by 1930, but because of the experience so gained, another industry—the manufacture of vacuum tubes—was developed in the same plants, which brought employment to 10,300 persons. In 1930 there were 574,000,000 lamps produced, which sold for an average price of 14.2 cents. This lower cost to the consumer, together with increased efficiency of the lamp and decreased cost of current supplied from central stations, reduced the cost of illumination to the consumer from $6.90 per 1,000,000 lumen-hours in 1920 to $3.50 in 1930.

The result of a number of other inventions, such as those relating to spinning, weaving and knitting, which are responsible for great modern industries, have not been presented because of inability to compare the numbers engaged prior to the fundamental inventions which made the application of power possible in these industries with those employed to-day

The museum traces in its exhibits the great inventions that have brought mechanical power to the aid of industry. These inventions are, of course, those of super-importance in this matter of employment. Mechanical power produced the industrial revolution and in so doing, produced the modern world. To trace the number of persons employed to-day because of the invention of the steam engine would be practically to compare the number of wage-earners in present-day Western Europe and the United States with the unknown number of wage-earners in these regions before the inventions of Watt in the late eighteenth century.

CHARLES R. RICHARDS

THE SCIENTIFIC MONTHLY

MAY, 1934

THE FAITH OF REVERENT SCIENCE[1]

By the Late WILLIAM MORRIS DAVIS

AT THE TIME OF HIS DEATH EMERITUS PROFESSOR OF PHYSICAL GEOGRAPHY AT HARVARD UNIVERSITY

PART I

Outline. The object of this address is, first, to direct attention to the enormous service of science in liberating our minds from their century-long subjection to ancient dogmas, thus enabling us freely to enjoy the modern understanding of the world and of our place in it, and second, to consider certain responsibilities that are placed upon us in consequence of our liberation. With this object the contents of the address are as follows: It will begin with an introductory statement concerning two great products of the human mind—religion and science. Then will follow several retrospects, the first of which will recall the harmonious relation existing between primitive religion and primitive science among primitive peoples; the second will touch upon the unhappy conflict which arose between struggling science and theologically dominated religion in the later centuries of European history; and, after a brief interlude, the third retrospect will tell of the victory of science over various theological elements of our religion in a recent era which might well, for that reason *alone*, be called the Victorian. In this short review it will not be so much the events of the several retrospects as the state of mind behind the events that we shall try to consider.

Then will follow a sketch of the actively growing reconciliation of Christian theology with modern science, which has so fortunately occupied the short period from the Victorian era to the present. After that, an outline will be given of the faith toward which multitudes of our population, who have become more or less conscious of the reconciliation just mentioned, are now advancing. There will then come some reflections on our new responsibilities in consequence of that reconciliation, and also a prognostication of the manner in which our new responsibilities can best be met, this being the main theme of my address.

Introduction. Two of the greatest products of the human mind are the various systems of faith known as religions and the various bodies of knowledge known as sciences. Both have slowly evolved from ancient and simple beginnings to their present complications; and the evolution of both appears to have been largely guided by outstanding leaders who have arisen from time to time in the two lines of thought. Religion is believed to have begun as a form

[1] The second Hector Maiben lecture presented at the meetings of the American Association for the Advancement of Science at Cambridge, Massachusetts, on December 28. Professor Davis died on February 5 in his eighty-fourth year. An appreciation by Professor John P. Buwalda, with a portrait, was printed in THE SCIENTIFIC MONTHLY for April.

of magic, in which the "medicine man" or shaman used certain incantations to compel the "powers" to act as he wished them to act. Later, when the powers were personified as deities, they were no longer compelled by incantations but implored by prayers and sacrifices to act as their priests wished. In its simpler stages religion was largely concerned with relations of humanity to the gods, in its more advanced stages it comes to be much concerned also with the relation of human beings to one another Thus we have the division of religion into its two parts, theology and ethics. Science must have begun among primitive peoples as simple observation, soon followed by elementary induction; but, as we now know it, science involves mental processes far too elaborate for primitive peoples. Like religion, it must have had a gradual beginning, and the beginning may have been as little like its present state as a seed is like a full-grown plant

At present religions are systems of faith which their devotees believe have been made known in smaller or greater part by inspiration or revelation from the supernatural world. Sciences are, on the other hand, bodies of demonstrable knowledge regarding the natural world, as far as it is open to observation and to inference based on observation. Both these lines of thought have come to be largely under the direction of two groups of specialists, the priesthoods of the churches and the professorhoods of the universities; but the priesthoods are supplemented by learned men among the laity, and the professorhoods are reënforced by many skilled experts in the arts and the industries.

Before going farther, let me repeat a significant word—the word "human." I have said the systems of religious faith and the bodies of scientific knowledge are both the products of the human mind That rejects supernatural revelation on which the followers of various religions believe them to be based. This statement may arouse dissent. Yet every one present will doubtless agree that all the sciences are purely human achievements. Most of those present will, I presume, accept also the purely human origin of the ruder religions of primitive humanity, perhaps including the hard religion of fear and punishment that was developed several thousand years ago among the barbarous Israelites. Many of those present may perhaps accept the wholly human origin of all the modern religions of to-day, excepting Christianity And some may believe, as I do, that all religions, ancient and modern, including Christianity, are, like all the sciences, wholly of human origin The grounds for this belief will be presented in the review of the recent reconciliation of Christian theology and science.

First Retrospect Our first retrospect is brief. It recalls the harmonious relation between the crude science and the rude religion of primitive peoples. If scientific explanation of natural phenomena is there attempted it is often wrong, largely because it is so commonly given a supernatural nature. For example, dwellers in arid regions do not ascribe the rains of their thunderstorms to the adiabatic cooling of ascending air currents, but to their rain god, to whom they therefore address prayers when rain is wanted. The priesthood has charge of such supernatural beliefs, and they develop them in accord with the rest of their religious system. Conflict between their science and their religion is thus avoided.

Second Retrospect. Our second retrospect deals summarily with the later European centuries. We there find at first one and later several priesthoods, each in charge of its own phase of Christianity. Let us remember that, as then taught, Christianity was little concerned with the simple ethical principles

preached by its founder; principles phrased in easily understood words and addressed to an uneducated population. Christianity of the Middle Ages and the next following centuries was largely concerned with highly theological creeds which had been adopted in earlier centuries by majority votes of humanly, not to say politically appointed delegates at the councils of a well-organized and dominant church. Moreover, some of the councils were held at times of violent metaphysical disputes within the church; in one instance about a matter so recondite as the difference expressed, as Gibbon puts it, by the vowel of homoouzion and the diphthong of homoiouzion.

It is truly singular that a great religion should be, not only then but almost to this present day, so largely concerned with the theology of complicated, majority-vote creeds rather than with the simple ethics of its founder; but such is clearly the case.[2] The explanation of this singularity is clear also; it is the result of ecclasiastical organization, and it has been through such organization that the peoples of Europe and of European stock have been so long held subject to a theologically dominated religion. And here let me state a very curious feature of that subjection. By reason of a strange concatenation of ancient events, the theological doctrines which have so long dominated European Christianity are the outgrowth of a series of crude, superstitious beliefs which originated several thousand years ago among the barbarous, ignorant, credulous peoples of southwestern Asia; a body of beliefs which was recorded, in the form commonly known to us, by a people who believed themselves "chosen" by their god from among all other peoples; a body of beliefs which was introduced into Europe in close association with a new gospel which that "chosen" people rejected, a rejection which later caused three centuries of cruel persecution. And yet we—that is, all peoples of European stock—adopted both the old beliefs and the new gospel as the infallible "Word of God" Does history record anything more extraordinary?

Is there any wonder that a conflict arose when European mentality began to assert itself? Those old beliefs, especially the cosmological myth standing at their beginning, were fitting enough for the race which, in the childhood of humanity, invented them. But how impossible it was that they should accord with the discoveries of science made by another race in another region under altogether different conditions!

Specifically, it was the heliocentric arrangement of the solar system, an old Greek view revived by Copernicus, which conflicted with the traditional position of a fixed earth in a geocentric system, as revealed in Genesis. Science, more or less aware of our many ignorances, tried by observation and reflection to establish a safe beginning of knowledge Theology insisted that a finality of knowledge had been given us on this, as on so many other subjects. Hence the Copernican system was condemned as heretical, and under the strongly organized Christian priesthood of that time, heretics had a terrible time of it. Even the protesting Luther said · "The fool"—Copernicus—"wishes to reverse the entire science of astronomy, but sacred Scripture tells us that Joshua commanded the sun to stand still, and not the earth."

Let it here be emphasized that the real significance of the conflict which thus arose did not lie so much in the difference of the two systems of astronomy as in the unlikeness of the reasons for adopting them and in the unlikeness of

[2] Edwin Hatch, "The Influence of Greek Ideas and Usages upon the Christian Church" (The Hibbert Lectures, 1888). Ed. by A. M. Fairbairn, London and Edinburgh, Williams and Norgate, 1890.

the minds which accepted those reasons. From the theological point of view, the relation of earth and sun was not to be studied; it was infallibly known and settled by revelation. From a scientific point of view that relation was, like any other problem, open to unprejudiced discussion. The scientific mind would be inclined to say that, if the revealed relation of earth and sun were true, it could only be confirmed by unprejudiced investigation, while if it were not true it would be thereby corrected. But the theological mind refused to take the risk of alternative conclusions, and it therefore opposed all such investigation. Thus the right of the human mind to think was infringed upon, its practise in thinking was lessened, and its progress in the difficult art of learning how to think correctly was retarded. In our freedom to-day, when investigation is aided and encouraged in every direction, we can hardly imagine how persistently it was hampered and opposed in earlier centuries. Experimentation in physics and chemistry was frowned upon if not suppressed. Philological study was retarded by the belief that Hebrew, as spoken by Adam and Eve, as well as by Jehovah and the Serpent, in the Garden of Eden, was the original language of mankind. The humane care and cure of the insane was long delayed by the theological belief that insanity was due to "demoniacal possession." Even in the nineteenth century the use of an anesthetic in childbirth was opposed by the orthodox on the ground that it avoided "part of the primeval curse upon women," although it was at the same time ingeniously defended by pointing out that in preparation for "the first surgical operation ever performed"—that of taking a rib from Adam's side for the creation of Eve—a "deep sleep" was caused to fall upon the rib-loser.

All this opposition was epitomized centuries earlier; for when the Franciscan friar, Roger Bacon, wished to increase his knowledge by experimentation instead of by deducing all truth from sacred texts, he was attacked on the ground that "he did not believe that philosophy had become complete and that nothing more was to be learned." He was forbidden by the "general" of his order to lecture at Oxford; his brilliant studies of the refraction of light in the production of rainbows were condemned because the rainbow was theologically believed not to be a result of natural laws but a "sign" supernaturally placed in the heavens to assure mankind that another universal deluge was not to be feared. And in his old age Bacon was imprisoned for fourteen years because he was "dangerous." How glorious is our mental freedom compared to the enslavement of those earlier times! When we realize the long struggle that our freedom cost our predecessors, should we not strive to use it worthily?

Let me close this retrospect by acknowledging my deep indebtedness to White's two masterly volumes on "The Warfare of Science and Theology in Christendom," from which the above statements are taken, and in which one may find the following general conclusion. "The establishment of Christianity . . . arrested the normal development of the physical sciences for over fifteen hundred years" (vol. 1, p. 375). Those who have not read this great work should do so without delay, for it will teach them many wonderful stories; for example, that of John Wesley, surely a man of no mean intellect, who nevertheless believed that spiders did not eat flies until after Adam sinned.

Interlude. Several eventful centuries elapse between our second and third retrospects, during which the spirit of scientific rationalism gained much strength; for this was an era in which the minds of Europeans were slowly

learning to work more and more independently of preconceived opinions With this growth of rationalism the number of heretical unbelievers—that is, unbelievers of various theological complications—greatly increased But that same era witnessed also some growth of the spirit of Christian ethics, and although unbelievers were still branded as heretics, the branding was only verbal, they were no longer burned at the stake

This era witnessed another manifestation of mental independence in the multiplication of religious sects, each one having its peculiar creed or organization based on Biblical texts which were still taken as the "Word of God," and elaborated in the mind of some able leader At the risk of repeating what is already well known to some of you, I wish to give a few examples of the theological doctrines which were then still in force, in order that you may contrast them with the relative freedom of to-day Nearly 300 years ago a famous "Confession of Faith" was formulated by a body of 150 learned and godly men who were summoned by an act of Cromwell's Long Parliament and were in close consultation for five years Two articles of this confession may be here cited. One of them sets forth again the old doctrine of original sin, which many a piously taught child of earlier times than now learned in its condensed, rhythmical form: "In Adam's fall we sinnèd all"; but which, phrased in more sententious form by those godly men, is as follows "From this original corruption"—that is, from Adam's sin—"whereby we are utterly indisposed, disabled and made opposed to all good and wholly inclined to all evil, do proceed all actual transgressions." There can be no question that this extraordinary article was authentically based on Scriptural texts; but there can also be no question that its doctrine is now so completely opposed by the teachings of evolutionary ethnology as to be scientifically absurd Can there be a more striking example of the manner in which ancient error was perpetuated?

But that is not all That now absurd article was supplemented by another which taught the perdition of most of the human race, because of a baneful clause found near the end of the Gospel of St Mark but not in the other Gospels; a clause now suspected by competent students to be spurious, for it is given as a saying of Jesus in spite of its violent contradiction of the spirit of his more authentic teachings, a clause which "has cost the world more innocent blood than any other" (White, II, 387); a little clause of only eight words, reading· "And he that believeth not shall be damned" (Mark 16 16) Chiefly upon that clause a monstrous conclusion was stated in another article of the above-mentioned "Confession of Faith," as follows "No men, not professing the Christian religion, can be saved in any way whatsoever than by becoming Christians, be they ever so diligent to frame their lives according to the light of nature and the law of the religion that they profess, and to assert and maintain that they may be is very pernicious and to be detested "

Had Jesus been present when that detestable article was adopted—he who taught us "Be ye therefore merciful, as your Father also is merciful"—would he not have said once more· "Father, forgive them, for they know not what they do " Or if that article had been found in a distant land, expressing the will of some pagan Juggernaut, would not all godly Christians have joined in condemning it as altogether opposed to the will of a loving and forgiving Father in Heaven? And yet, under abject submission to ancient myths and to very fallible records of later date, those 150 earnest, devoted, conscientious men compelled themselves to believe that monstrous

theological doctrine, with its imagined alternatives of perdition and salvation!

Third Retrospect. The conflict between the theological elements of Christianity and science reached a climax in the Victorian era, to which our third retrospect is directed, because science had by that time gained immensely in strength and independence. Not long before that era opened, the past history and the future continuity of the earth had been shown to be vastly longer than the Bible taught. As the Scotch geologist, Hutton, put it: "In the history of the earth there is no trace of a beginning and no prospect of an end." Then, shortly after the era opened, the antiquity of man was shown to be much greater than the few thousand years which the Biblical chronology allowed it. And but little later, Darwin, after holding his growing ideas under "study and meditation for nearly twenty years," announced his revolutionary, evolutionary theory, including man's development from some anthropoid mammal, and thus presented a new philosophy to an unwilling, a very unwilling world.

It must not be imagined that the makers of these great discoveries had been working with the object of unsettling religious opinions; not in the least. They were devout men, possessed of vigorous intellectual curiosity, who were objectively pursuing geological and biological studies simply with the wish to learn the truth, whatever the truth might be. They rarely if ever precipitated a conflict by attacking the theological beliefs which their discoveries traversed. The attack was made by the theologians, most of whom were wholly untrained in scientific habits of thought. When the above discoveries, particularly Darwin's, were announced, the violence of the protests they aroused among the orthodox can hardly be credited to-day. Men learned in Christian theology then asserted, "Darwin requires us to disbelieve the authoritative word of the Creator"; and again, "If the Darwinian theory is true, Genesis is a lie, the whole framework of the Book of Life falls to pieces, and the revelation of God to man, as we know it, is a delusion and a snare." Not twenty years ago, a preacher told his congregation that God had made monkeys look like men so that heretics should be led into error! In a word, the clergy of the Victorian era, as well as some of their successors, were still as much blinded to the grandeur of the evolutionary scheme of the varying organic world as their predecessors had been to the grandeur of the Copernican scheme of the solar system. It is therefore gratifying to know that, some twenty-five years after Darwin's "Origin of Species" appeared, a broader view of the world was taken by Bishop Temple of London who wrote: "It seems something more majestic, more befitting Him to whom a thousand years are as one day, thus to impress His will once for all on His creation, and to provide for all the countless varieties [of organic forms] by this one impress, than by special acts of creation to be perpetually modifying what he had previously made."

A curious feature of the objection to Darwinism was that, while it strained at the little gnat of specific evolution, it unhesitatingly swallowed the huge camel of individual development. Of these two processes the latter is immensely the more marvelous. It involves for every individual the change from a slightly differentiated ovum into an elaborately differentiated adult, closely resembling its parents; and during this change there is, first, a rapid recapitulation of many ancestral antiquities, and later a more gradual addition of certain evolutionary novelties. On the other hand, the appearance of a new species involves only the addition of a few extra-novelties, highly significant for the species then appearing, but nothing like so wonderful

as the long sequence of inherited antiquities which precedes them. But the huge camel of individual development was, like the magnificent phenomena of sunrise and sunset, a familiar commonplace which the Mosaic record took as a matter of course, while the little Darwinian gnat of specific evolution was a choking innovation, which the Mosaic record explained by supernatural acts. And these supernatural acts were believed in by the multitude, because the unscientific mind desires a supernatural power to enter frequently into mundane affairs, where the scientific mind sees only the orderly working of nature.

The story is told of an African chieftain who, thirty years ago, watched the construction of the steel-arched railway bridge across the gorge of the Zambezi. At its beginning he told the engineers: "You can never build it across." When it was built across he said: "It can not bear the weight of a train." Finally, when a train was safely driven over it, he said: "The finger of God holds it up." But the engineers said: "The bridge stands and bear the weight of the train because of the strength of its steel." This story has a long moral. Many devout Victorians, sixty or seventy years ago, could not believe that anything so marvelously intricate as the development of successive organic forms could be accounted for by natural processes. Like the African chieftain they could not leave out the "finger of God." But Darwin said: "I believe in the doctrine of descent with modification, notwithstanding that this and that particular change of structure can not be accounted for, because this doctrine groups together and explains . . . many general phenomena of nature." And the grandchildren of the devout Victorians now, with no loss of devoutness, follow the belief of Darwin rather than that of their grandparents. Such is the order of human progress.

But why repeat these old stories of the Victorian era? There may perhaps be present some persons who are so completely modernized that they look upon that era as already too much talked about, because it was so fatiguingly prim and platitudinous. Truly, its earlier years were rather prim, for church-going two or three times every Sunday was then a matter of course for the piously respectable part of our population: but it is that very primness which must be understood if we, much less prim, are to measure our indebtedness to science for having led us out to a more vigorous life.

It must be remembered that hell and the devil were vivid realities to devout Christians in those recent days; and that some very orthodox parents then taught their children an awful catechism. The loving parent would ask: "Doth original sin wholly defile you, and is it sufficient to send you to hell, though you had no other sin?" and the little child was to answer, "Yes," though no child could possibly have any adequate conception of that shocking doctrine. Again, when asked: "What is your natural state?" the little one was to say: "I am an enemy of God, a child of Satan and an heir to hell." Could anything be more incredible? Yes, more incredible still, parents were informed by the authorities of their church that it was proper, even before the little ones had learned to read, to teach them those frightful answers and others equally far beyond childish understanding. There are actually men now living who were taught that sort of thing in their early years by their fathers. Do any of those men, I wonder, now teach the same catechism to their sons? Very few of them do; and it is to scientific rationalism that they owe their deliverance from such folly. If the question is again asked, Why repeat this old story of the Victorian era? the further answer may be given: It is

repeated in order to show the younger generation of to-day, who are now growing up in ignorance of such stories, how recent is the escape of many of us from the theology of medievalism, based on ancient myths

It is truly difficult to believe that such theological beliefs were persisted in by devoted, conscientious men, who therefore violently opposed anything so heretical as Darwinism On the other hand, there were also many liberalized rationalists who welcomed the new discoveries and rejoiced in the better understanding of the world that they provided But there was an intermediate and very important class of Victorians, for between the unyielding conservatives and the open-minded rationalists was a large number of somewhat mobile-minded yet still orthodox believers, who could not altogether reject the new discoveries, although they had a hard time accepting them. Many of those earnest men suffered great mental distress on finding that certain elements of the creed which they had been taught as essential verities were so inconsistent with the findings of science that they must be regarded as erroneous. And the more logical of them perceived, with still further distress, that if the Bible, which they had been taught was infallible from cover to cover, were shown to be fallible in one or more of its parts, the infallibility of the rest was thereby made questionable, to say the least. To what guide should they turn if the guide that they had so devotedly trusted proved to be not wholly trustworthy? Moreover, if they gave up the infallibility of the Bible, would they not thereby forfeit the right to call themselves Christians? That fear caused profound unhappiness to many sincere men before they found their new bearings But some of them at least were wisely shown that if they followed the example of their orthodox predecessors in studying and interpreting Christ's teachings under the best advice they could get, and if they then still experienced a joyful exaltation over the profound ethical value of the teachings and a warm desire to live in accordance with them, they would have just as good a right to count themselves among his followers as any one else In that happy conviction, thousands and thousands of former conservatives, liberalized by the discoveries of science, are living to-day.

It is as if the mobile-minded orthodox believers of recent time had been near the top of a long flight of stairs, each step of which represented an article of faith, and on or near the top step of which their great-grandfathers had stood. Wherever the mobile-minded orthodox found themselves, they at first insisted they would never take a single step downward. Then in a few years, finding themselves, in consequence of more or less unconscious thinking, several steps lower on the long flight, they again insisted they would never descend any more But they did, step after step; and many of them are now not far above the solid ground of rationalism at the bottom of the flight. If they should turn and look back at the long flight, they would marvel at the insecurity of the scaffolding that holds it up! And if they there conferred with one another, they would say. "How few of us to-day hold all the beliefs that our fathers so ardently held!"

Scientific Study of Religions. One of the most potent causes of disconcertment to orthodox theologians, not yet mentioned, was actively at work all through the last century; namely, the application of the objective, scientific method, not alone to the study of plants and animals, not alone to the study of the structure and history of the earth and of the distance and composition of the stars, but to the study of religions. In spite of their wide diversities the religions of the

world were thus found to show a broad community of content and an inherently human origin. They very generally make more or less definite claim of intercourse between their founders and their gods, or of revelations *to* their founders *from* their gods, or of miracles which attest the power of their gods or the authority of their founders. Some religions are found to be more, some less refined in their ethics; but whatever form they take, they reflect much of their natural environment. Among the factors of environment must be included the characteristics of the people who develop them, as well as the climate and the topography of the region in which the people live. In an open country where occasional mountains rise over lowlands, mountain tops have repeatedly been chosen as residences for the gods, or as sites for altars where sacrifices to the gods should be most fittingly made. It is on the seacoast that a god of the sea is worshipped; it is in the desert that a god of rain is worshipped. That is, the gods vary with the homes and the needs of the people who pray to them; they vary also with the ethical standards of their worshippers.

But whatever the quality that a religion acquires, its believers, knowing little of any religion but their own, naturally take it to be superior to all others; its gods are the greatest gods; its people are divinely favored This self-centered belief has made many an ardent young Christian missionary much harder-hearted and harder-minded than he should have been with respect to the beliefs of the heathen whom he was sent out to convert to what he earnestly believed was the only true faith. In contrast to that self-centered belief, the more sympathetic belief of the student of religions is such that he comes to see in every religion the striving of humanity toward a fuller understanding of man's place, man's opportunity and man's duty in the world. And this surely makes for brotherhood and good will among men The change that has thus been made desirable in missionary work is most beautifully and understandingly set forth in a remarkable report[3] made last year by an interdenominational "Commission of Appraisal" of fifteen members, who visited India, Burma, China and Japan. Further reference will be made to it later.

Great benefit has been conferred upon Christianity from scientific study of another kind, closely related to the scientific study of religions; namely, from the scientific study of the Bible, the so-called higher criticism This study has applied a most helpful correction to the beliefs of irrationally convinced credulity by the use of impartial rationalism. One may now, guided by the illuminating results of such study, appreciate the great value of the Bible as a venerable human work; manifestly human in its naive record of various scandalous stories about its leaders as well as in the candid record of successive stages in a great advance from savagery to barbarism. Moreover, as long as the Bible was regarded as the infallible "Word of God," there were persons who, with more sense than sympathy, scoffed at it because so many of its passages are ungodly But the ground is taken from under the feet of scoffers when the human origin of the Bible is recognized; for then its cruder passages are seen to be only the inevitable imperfections of struggling humanity, with which we, still struggling *to-day*, must warmly sympathize.

If some passages in the Old Testament are fatiguing in their enumeration of the generations of Adam or of the places where the Israelites "pitched" during their traverse of the Wilderness, many

[3] "Re-thinking Missions," by the Commission of Appraisal, W. E. Hocking, *chairman*. New York, 1932.

of its passages are inspiring. How grand is the solemnity of the first four words: "In the beginning God." Even a rationalist must respect the devoutness of the nineteenth Psalm: "The heavens declare the glory of God; and the firmament showeth his handiwork." Where can be found a finer gem of reverent thought, even though it lies amid much dross, than Micah's declaration: "For what does the Lord require of thee but to do justly, and to love mercy, and to walk humbly with thy God." And if some passages in the New Testament, especially in Revelations, are extravagant, who can fail to marvel at the words of Jesus, uttered in an age of violence: "Love ye your enemies, and do good . . . and ye shall be children of the Highest; for He is kind to the unthankful and the evil. . . . Be ye therefore merciful as your Father is also merciful." His reputed miracles in the way of casting out devils are as nothing compared to his clear perception of the value of gentle goodness.

The Recent Period of Reconciliation. The transition from the Victorian era to the present time is of particular interest to those of us who have lived through it, not only because it has witnessed an unprecedented advance of science, but even more because it has been characterized by an amazing reconciliation of Christian theology with science. To be sure, there are still many earnest preachers who, like the conservative hold-fasts and die-hards of 80 years or more ago, can not give up the beliefs of their fathers. Instead of being the leaders of their congregations into the newer understanding of the world, they are vainly striving to hold them back in the older misunderstanding. This is because they were treated when young very much as the children of the Flathead Indians are—or used to be—treated. Stiff boards were bound to the Indian children's heads, so as to flatten their skulls as their parents thought they ought to be flattened. Similarly, the children of the ultra-orthodox Christians have had stiff theological creeds and catechisms bound to their minds, so as to shape them as their elders devoutly thought they ought to be shaped. It is therefore most natural that, when such children grow up, their minds remain so shaped, they can not reshape them if they would, especially not if they become ministers pledged to maintain the stiff beliefs to which their minds were bound in their growing years

It was a mind-bound conservative of this kind who not long ago exclaimed: "If I could not believe that Joshua made the sun stand still in the heavens, I should lose faith in the Bible and in God." He had probably been educated in one of those sectarian colleges, to which orthodox parents send their sons to safeguard them from scientific error. It was as a teacher in such a college that a young Harvard graduate was some years ago, as he later told me himself, instructed on his arrival there by the president of the institution: "You may teach as you like about minerals and rocks, but if the students ask you about the age of the earth, refer them to me."

Theologians would have found their change of belief easier had they been scientifically educated, but they have not been. They have presumably studied "apologetics," in which they learned how to argue out a problem; but that method of argumentation is not free; it is directed to the support of a predetermined conclusion and is therefore absolutely unscientific. The essence of scientific method is that it gives equally impartial consideration to all conceivable solutions of a problem, and adopts the one which pragmatically works best, after it has been tested by many men in many places through many years. But it is recognized also that the human mind is not infallible, and therefore all

adopted solutions are open to revision whenever new evidence bearing upon them is discovered. It should be understood, however, that scientific method thus characterized is a modern development, the result of centuries of experience; for although the science of logic is of more ancient origin, its unprejudiced application to scientific problems is difficult to learn, even in scientific schools; and it is probably never learned in theological schools.

In spite of all obstructions, liberation from outworn theological creeds seems to have been repeatedly accomplished during the period of reconciliation, even among conservatives, by a gradual and insensible shift of belief. The shift has rarely been caused by direct argument, and it has nothing whatever in common with the hysterical conversion to religion of old-fashioned camp-meetings. The shift is in great part a consequence of the simple process of growing up in the rationalized atmosphere of modern times. The present generation has become habituated to accepting the results of scientific discoveries. It has at the same time become increasingly incredulous about miracles, which are now more and more overlooked, neglected, forgotten. Along with the rationalizing influence of scientific progress has been a marked lessening of the antagonism which used to prevail between religious sects; and a falling-off in the number of severely doctrinal sermons, the kind that used to expound "hell-fire religion."

There has also been a marked relaxation regarding matters of belief. One of the most striking instances of this kind was that by which the implied damnation of non-elect infants was omitted from the confession of faith of one of our most important denominations. Many of the laity and clergy had practically ceased to believe it, and finally at a General Assembly of the church in Philadelphia about thirty years ago, the phrase "Elect infants dying in infancy are saved" came up for discussion. A motion was made to strike out the word "elect," and the Conservatives objected that there was no specific Scriptural evidence that all infants were saved. In the vote which followed, however, they were decisively beaten and it was then officially declared in the faith of that denomination that "Infants dying in infancy are saved." When the motion was declared carried, an elder arose—he must have had a keen sense of the humor of the situation, in which a majority vote of ministers and elders could be taken as deciding how their God would act—he arose and said: "I move that vote be made retroactive." The solemn assembly was overcome with laughter. Let it be noted that that antiquated doctrine was not argued away; it was simply sloughed off by the weight of its inherent absurdity and soon forgotten. Should we not be very grateful to the growth of scientific rationalism by which so monstrous a belief was crowded out of acceptance?

The rapid advance of rationalism during these recent years may be seen by comparing the beliefs held at successive ten-year periods in the life of a single individual. It has been written by an experienced evangelical clergyman that "the recognition of the orderly working of nature weakened confidence in the miraculous, and as years passed theologians . . . interpreted scenes, teachings and epistles of the Bible in a way that would have shocked themselves ten years before." We may tell further of a man of altogether admirable character who had been taught as a boy the standard Christian myths, such as that of the devilish serpent which talked with Eve in the Garden of Eden; and who, after giving up those childish beliefs in his early manhood, found that still further liberalization was experienced in his mature years. He thus in a single life-

time came down many steps from near the top of the long flight where his excellent father had stood, but he is not yet at the bottom. However, if he lives a few decades longer he may, after interpreting the Bible's teachings in a way that would shock himself to-day, come farther down, nearer the solid ground of wholly rational belief at the bottom of the flight. Many examples of this rationalizing process may be found among one's friends, if not in one's own experience

There is one disappointing element in this story. It has often been claimed that the marvelous progress of civilization in Europe has resulted from the adoption of the Christian religion; and it would be indeed gratifying to know that the refined ethics of Christianity have really brought about that progress But in view of the dependence of European civilization largely on the advance of science, which did not begin until the revival of learning, centuries after the adoption of Christianity, and in further view of the persistent opposition with which the organized forces of Christianity so generally resisted the advance of science even in so beneficent a study as medicine, and in still further view of the dominance even to-day of many non-Christian principles of behavior among peoples of European stock, the claim that European civilization is a result of Christianity can be allowed only in part, perhaps only in small part. Modern European civilization is the result of mental rather than of moral achievements, and as such it is more closely associated with the mentality of European peoples than with the religion which they adopted nearly 2,000 years ago, the ethics of which they have not yet learned to practise Had they done so, the claim would be more true. It may, indeed, be seriously doubted whether Christian ethics had much to do with the adoption of organized Christianity by early Europeans. They were an ignorant, superstitious, credulous, warlike and cruel people, and it may be well believed that they made professions of Christianity less in order to practise, during their lives on earth, the lofty ethical principles preached by its Founder, than to secure for themselves through a vicarious atonement for their natural sinfulness a blissful future life in heaven promised by propagandizing theologians, and thus to escape a threatened eternity of torture in a horrible hell

Human Origin of All Religions. It was said at the beginning of this address that all religions, like all sciences, should be regarded as the natural products of the human mind It was added that the grounds for that belief would be stated in this part of the address. The grounds are these. First, as to Christianity: Many theological elements of our religion, based on Scriptural texts, have been shown by scientific research to be erroneous; they can therefore be no longer taken as infallible revelations; they are only humanly invented beliefs, accepted by the ancient Asiatic people who recorded them. But various other elements of our religion are still held by conservatives to be of supernatural origin. They are so held on the evidence of other Scriptural texts; and these other texts, being of essentially the same nature as those formerly held to demonstrate the supernatural origin of the abandoned beliefs, can no longer be taken as competent witnesses to the truth of the remaining supernatural beliefs. Hence these remaining beliefs should also be interpreted as humanly invented. The upshot of this is that, while the Bible unquestionably gives us an invaluable record of the beliefs of an ancient people, the competence of its texts as witnesses for the supernatural is invalidated. The same argument applies to all other religions, but with less

directness because they have not come into conflict with science so much as Christianity has.

A corollary of this conclusion is that the precepts of our religion should be accepted not on authority but on merit. They should be judged, just as we judge the precepts of other religions, by their appeal to our moral sense. In support of this conclusion let us recall the various traditional beliefs which, passed down to us from an ignorant and credulous people, were for centuries held to be essential elements of the theological part of our religion: recall the proposed replacement of those beliefs by the findings of science, won from nature by patient, truth-loving research; recall the vehement protests conscientiously made against such replacements because they contradicted the "Word of God"; recall finally the gradual fading away of the protests and the acceptance of the protested replacements. What a striking resemblance there is in all these stories; the same sequence over and over again. Should we not learn from so uniform a repetition of the same experience that the Bible is, as just said, not a competent witness to the occurrence of supernatural events in human history, and that it should be studied as other human records are studied?

But let another matter be recalled. All the discarded elements of Christianity thus far noted are of a theological, not of an ethical nature. The ethical elements of Christianity have not been disturbed; they have not been discarded, even by those who believe in the humanity of their great preacher. Nor has the value of the ethical elements been lessened in the least by the abandonment of the theological elements. The great principle, "Whatsoever ye would that men should do unto you, even so do ye also unto them," is still as valid as ever. Indeed, its validity has been strengthened by the comparative study of the races and the religions of mankind. In a word, the whole drift of scientific opinion through the centuries since the revival of learning has been away from theological superstition toward rationalism; and during the same centuries, Christian ethics have been gaining ground. This is true, notwithstanding the fact that the principles of Christian ethics are, like those of the ruder ethics which they have displaced, increasingly regarded as of purely human origin, quite as much so as tables of logarithms or of chemical elements.

It is, of course, to be expected that many persons will dissent from the untraditional views just expressed and will continue to believe that, however human other religions may be, our own Christian religion is truly based on supernatural revelations; and they will thus resemble the African chieftain who believed that the finger of God gave an otherwise incredible strength to the Zambezi bridge To them should be told the story of George Fox, founder of Quakerism, and his convert, William Penn. George, meeting William not long after his conversion, said: "William, I see thou art still wearing thy sword." "Yes," said William, "it seems best to wear it." "Wear it as long as thou canst," replied George, and the next time they met, William wore no sword. The moral of this story is that those who still devoutly believe in the occasional interruption of natural processes by supernatural processes should continue to hold that belief as long as it is helpful to them. Only when it ceases to be helpful should it be set aside. But that such beliefs have repeatedly ceased to be helpful is shown by the vast number of modern William Penns who have rationally given up wearing their theological swords in the last seventy or fifty or thirty years.

The change of mental habit thus indicated has been astonishingly rapid; more

rapid, indeed, than corresponding changes have been made in the creeds of rationalized church members. Indeed, many churchmen have been led by orthodox preaching to think that theological beliefs constitute so essential a part of Christianity that, when they found those beliefs no longer tenable, they thought they no longer had any religion. This is greatly to be regretted, for the majority of those men really still hold the essentials of Christian ethics in their hearts as their ideal.

Before turning to my next topic, let me point out one feature of the growing reconciliation of Christian theology with science that is of especial significance. The reconciliation is not a compromise, in which each side has yielded something. It has been brought about wholly by the modification of theological views so as to bring them into accord with scientific views. Not a single one of the various scientific discoveries which, at the time of their announcement, proved to be so disconcerting to the orthodox, has been reversed. On the contrary, the estimates of the earth's age and of the antiquity of man are now greater than when they were first calculated; and the evidence in favor of organic evolution is immensely stronger than it was in Darwin's time. True, there was a flurry some twenty years ago, when an eminent English biologist, Bateson, declared in an address at Toronto that "Darwinism is dead," or words to that effect. The half-informed public misunderstood him to mean that evolution is dead. He meant nothing of the sort, for he was a pronounced evolutionist! What he meant was that the process of natural selection, which Darwin had thought was the mainspring of evolution, was in his opinion inadequate, and that evolution had been brought about in some other way.

Part II

Clearing the Ground. Before taking up the "Faith of Reverent Science," to which the foregoing pages may serve as a preface, let a word of warning be introduced. Thus far much has been said of various outworn theological beliefs which have been displaced by rational beliefs. Perhaps that has given the impression that the object of my address is destructive. Not so! The object of the address is constructive, in that it places great value on the sounder beliefs which have replaced the outworn beliefs. The case is like that of our pioneer forefathers, who had to clear away the forests before they could plant their productive crops. Similarly, science has had to clear away old errors before it could implant new truths; but that is a wholesome, constructive process. It is, however, because of the abandonment of the outworn beliefs by scientific rationalists that the orthodox have so often given them the derogatory name of unbelievers, although the rationalists felt themselves to be just as ardent believers of the faith that they maintained as the orthodox were of theirs.

What, then, are the beliefs of scientific rationalists? No one can say definitely what they are, because rationalists have not organized themselves into a religious body and therefore have not as a body formulated a creed. No one is authorized to speak for them; they are individualists; like St. Paul, each one holds his own gospel (II Tim. 2: 8). This is, in one respect, unfortunate, because, standing alone, they lose the great advantage of concerted action; but, on the other hand, they conserve a freedom of thought, which organization is likely to limit. They might, however, unite in neighborhood churches, where each member would be "free to follow truth as he sees it to its uttermost bounds," yet at the same time "enjoy religious fellowship with others and work together for the common good."

But besides being unorganized there are, among scientific rationalists, as among other groups of our population,

persons of unlike temperament: some of them take religious matters lightly, inattentively; others of them take such matters seriously and reverently. It is with the latter sub-group, whose faith may therefore be called the faith of reverent science, that we are here concerned. It is highly significant that, as far as I can judge from a considerable acquaintance among them, they hold many of the essential principles of Christian ethics. Those principles are, as already told, fortified by scientific research, not only because they harmonize with the great modern truths which have supplanted Biblical myths, but also because so many of them are represented in other great religions, also of human origin like ours.

The Faith of Reverent Science. The chief articles of the faith of reverent science, thus understood, may be summarized as follows.

(1) Reverent science devoutly refrains from assuming to know the nature, the thoughts, the acts of a Supreme Being by imputing even the best of human acts and thoughts and nature to him. It stands humbly silent before the ever-expanding mystery of the universe. In the sincere agnosticism of profound ignorance regarding the supernatural, no satisfaction is found in the limitations of a Supreme Being which invariably accompany the attempt to define him. Let no one make the blunder of confusing this agnostic attitude with atheism: inability to form an estimate of a quantity is no ground for saying its measure is zero. Recognition of our ignorance regarding supernatural matters goes with the growth of our knowledge regarding natural matters. It was appropriate enough in Noah's time, when little was known of the world, that a legend should describe a creator who repented of his creation. Somewhat later, Moses still knew so little of the world around him that he did not hesitate to define his chief deity in very human terms, even to the point of conceiving him as being shamed out of his wrathful threats by human reproaches. From then till now a long series of concepts has been promulgated, generally becoming more refined as time went on, although one of the most popular included a malevolent Devil working in conflict with a beneficent God. The humanly inconceivable quality of immanence came to be attributed to Deity by metaphysical theologians, but that quality must be terribly strained, even to metaphysicians, now that the universe is found to extend, along only a part of one of its dimensions, for 300,000,000 light-years. It is on reviewing these various unsatisfactory hypotheses that the reverent scientist retreats to humble silence.

But by no means are all scientists silent agnostics in this matter. One of our leading physicists is reported to have said: "It is through science that man has discovered that his own soul is God's greatest purpose in the universe": but it is not explained how the discovery was made. Another defines the "God of science" as the "spirit of rational order"; but without going on to specify the place that is occupied in rational order by the terrible griefs caused to humanity by irresistible hurricanes, devastating floods, incurable plagues and above all by barbarously irrational wars.

Agnostics are baffled by the cruelties and miseries of the world; always a marvelous and often a beautiful world, but also for ages and ages a merciless world, on which, even while the gentle rain fell from heaven, carnivora remorselessly devoured herbivora; and even now sometimes a terrifying world, as when an unforeseen earthquake wave sweeps away a whole village of simple fisherfolk; and too often a cruel world, in which, until a few years ago when

medical science came to their relief, countless innocent and devoted young mothers have had, through no fault of their own, to endure the agony of seeing their little ones, whom they had no power to cure, strangled to death before their eyes by diphtheria. The mystery of such a world is too profound for our solution. The easy invention of a devil gives no acceptable aid in understanding it. Hence in no spirit of irreverence but only in the sincere humility of acknowledged ignorance does the agnostic refrain from making assertions regarding a Creator.

(2) Reverent science has a secure faith in the persistence of the order of nature through time and space, because such persistence has repeatedly been shown to be in the highest degree probable; but it is not absolutely proved; science has no means of reaching absolute proof in matters of such magnitude. Yet in view of this faith, certain reported events, known as miracles, which interrupt the order of nature, are discredited because there is no sufficient evidence forthcoming that they have ever taken place. Such disbelief is confirmed by the historical fact that alleged miracles are usually reported from ignorant and uncritical communities. With the vanishing of belief in miracles, legions of elves, gnomes, imps, witches, demons, devils, fairies, spirits and angels have also vanished from among us.

It is not alone among rationalists that miracles are disbelieved to-day. Many of our orthodox churches now discredit certain Biblical miracles which, a generation ago, were literally believed. Consider, for example, the miracle performed by Christ in calling forth devils from a demoniac, and at their entreaty giving them leave to enter a herd of swine. Is there to-day any one who believes that the demoniac was possessed by actual devils; or that when they came forth from him they orally besought Christ to let them go into the swine; or that, on being given leave, they actually entered the swine? Does not every one now take the central episode of the story to be an example of more or less hypnotic healing, and then interpret its miraculous elements as legendary attachments demanded by the ancient belief that certain diseases were due to possession by devils; the swine being introduced as the best means of disposing of the devils when they came forth from the demoniac.[4] And when thus interpreted where is the miracle?

The orderly wonders of science would have been taken for miracles by peoples of ancient and medieval times, as they still are by modern savages. Some of them may well seem miraculous, even to intelligent moderns Consider, for example, the computation of a comet's orbit, as worked out by Gauss on the basis of Newton's laws. A new comet is ordinarily, when first seen, only a small and faint nebulous wisp, with neither head nor tail. Its distance from us and its direction and velocity of motion are unknown; yet if three observations of its apparent position among the stars are made at intervals of about a week, as it is seen from our revolving, rotating earth, it is then possible to calculate not only its distance from us and the direction and velocity of its motion at the times of those observations, but also where it will be seen among the stars and how it will be moving at any desired date for a considerable period of time in the future. This suffices to show how enormous is the range of human mentality, a conclusion that should not be forgotten when we are tempted to regard the announcement of new ethical principles as necessarily indicative of superhuman powers.

(3) Reverent science believes that various communities or tribes or peoples

[4] The long-continued opposition of theologians to medical science is broadly treated in White's "Warfare. . . ." II, Ch. xii.

have, through their purely human efforts, gradually formulated not only their theological beliefs but also such rules of behavior, or codes of morals, or principles of ethics as seemed fitted for their needs in the successive stages of savagery, barbarism, civilization and enlightenment. It is therefore concluded that, like all other codes, the Christian code has been humanly formulated instead of supernaturally revealed. A strong support for this conclusion is that many of the so-called revelations of the Bible do not seem beyond man's own discovery; also, that the essential equivalents of many Biblical revelations are found in other religions.

Moreover, the human origin of the Biblical systems of ethics, as well as of other systems, is strongly indicated by their gradual improvement with the passage of time and with the progress of the peoples who formulated them. Let us not forget in this connection that, if we go back far enough, lying, stealing and slaying have not always been "wrong." Such acts were instinctively "right" among our semi-brutal ancestors, and they did not become wrong until, after thousands and thousands of years of experience, they were first condemned by moral leaders, and later condemned by the local public. Similarly, some acts which we consider right may be in time condemned by our improved descendants. It is truly difficult to believe that "right," as we know it, is not a matter of objective reality but only of subjective human opinion, subject to change as humanity advances. Many persons may refuse to believe that acts which we hold to be wrong were ever right; yet such acts had, in their time, just the same claim to be right as our gentler and more merciful acts have today; namely, the general approval of their communities as guided by their leaders: for example, Moses, the great law-giver, boasted of how he had taken all the cities of Sihon, "and utterly destroyed the men, and the women, and the little ones, of every city"; and of how he had likewise taken all the cities of Og, king of Bashan, "utterly destroying the men, women, and children of every city" (Deut. 2 34; 3: 6). Centuries later, the gentle little Samuel thought, after he had outgrown his childish gentleness, that it was his Lord's wish—and therefore surely "right"—that Saul should smite the Amalekites and "slay both man and woman, infant and suckling." And therefore Saul "utterly destroyed all the people with the edge of the sword," sparing only Agag, the king; but Samuel made up for that sinful omission, for he himself "hewed Agag to pieces before the Lord" (Sam. I, 14)

It is truly a difficult proposition to believe that what we think is "wrong" could ever have been "right" Many persons may shrink from accepting it; but what other conclusion can we reach if we face the facts; that is, if we study open-mindedly the evolution of savage man from brutes and of civilized man from savage man Thus explained, an evil act of to-day, whether it be a sin against a religious code or a crime against a civil code, is generally nothing more than an act that was permitted and condoned in an earlier era, but that has come to be condemned and prohibited in a later era. The torture of prisoners of war was once a matter of course; now it is as a rule no longer sanctioned. Human nature has changed for the better.

(4) Reverent science preserves an earnest faith in the value of sacrificing one's own selfish preferences for the common good and of prayerfully consecrating one's best efforts to the betterment of humanity; but it has very generally given up the belief in the possi-

bility of turning the course of events, which are beyond one's own control, into a desired direction either by the sacrifice of animals or by the prayer of humans. A waning belief in the efficacy of prayer is one of the most marked effects of the waxing influence of rationalism. It goes with a fuller realization of the persistence of the order of nature. More than any other phase of rationalism it varies with personal temperament. Many persons no longer pray for rain during a drought, because they have come to understand that rainfall results from natural movements of the atmosphere; but the same persons may pray for the recovery of a friend from illness, perhaps because of a feeling that human affairs are less physical, more spiritual than atmospheric movements Yet science has shown that human illnesses involve conditions and processes that are quite as natural as those which control rainfall, even though organic instead of inorganic. But what shall be said of a hospital which announces on advertising cards in London buses that it is supported wholly by prayer? If it be so supported, why should such an announcement be posted?

(5) Reverent science accepts, without asking that it shall be revealed to us, whatever fate is in store after death, be it immortality or annihilation, in the complete trust that it is a fate fitting the part we have to play in the unfathomable mystery of existence. It leaves aside all transcendental questions about the imagined regions of heaven and hell, and it rejects absolutely the monstrous doctrine that most of mankind have long been and still are condemned to horrible torment after death, also the specious doctrine that salvation from such a fate has been and is still granted to but a small minority of mankind, and to them only through vicarious atonement for sin they never committed, the original sin of a fictitious Adam. The jealous Jehovah visited, according to Moses, "the sins of the fathers upon the children unto the third and fourth generations," but Christ's merciful Father in Heaven has been made by some would-be Christians unforgiving to the children of countless generations of those that never had opportunity of hearing of him. The persistence of this doctrine of damnation into our times must do serious injury to Christianity in the minds of intelligent "heathens."

Let me draw special attention to the first two lines of this article: "Reverent science accepts, without asking that it shall be revealed unto us, whatever fate is in store after death." This acceptance of ignorance of the unknown is characteristic of an honest scientific attitude with regard to an unsolved problem. A suspended judgment is maintained, which refuses to settle down on an unwarranted solution. That attitude is distasteful to the scientifically untrained; they do not wish to suspend judgment; they wish to adopt some preferred solution instead of remaining agnostic in the absence of a demonstrable solution. It sometimes seems as if not only persons of untrained minds, but also certain highly trained philosophers and metaphysicians were likewise unwilling to suspend their judgment; for, after discussing problems that are far beyond solution by scientific methods, they appear to settle down on one or another solution of such problems, their choice being guided more by subjective preference than by objective proof.

(6) Reverent science is much concerned with making our life on earth as good, as unselfish and as helpful to others as possible, not in order to receive posthumous reward for doing so, nor in fear of posthumous punishment for not doing so, but in the convinced belief, based on long human experience,

that in a life so conducted—a simple, kindly, helpful life—man finds his highest and deepest satisfactions and his fewest regrets; a convinced belief that doing good in a sincere and unselfish spirit is man's best means of maintaining the progress of the past and of contributing to the progress of the future; a convinced belief that in so conducting his life he is playing the best part accessible to him; and that while so conducting it he will find his truest happiness in his home, with his neighbors, among his countrymen and over the whole world.

Summary. The foregoing articles of faith suffice to show that no one who holds them should be called an unbeliever; for they represent the essence of Christianity, after many mythical, miraculous and theological elements have been withdrawn from it. Alas, that it is so much easier to state these articles than to practise them! Alas and alas, that even while earnestly believing them one may fail and fail again to live up to them. Without making that confession I should not be willing to write these pages.

One of the large merits of such a faith as that above outlined is that it may easily keep pace with the growing knowledge of the world. No one who holds it would be content to use, as his guide, a creed formulated centuries ago by majority votes of credulous and disputatious theologians and based on texts several centuries older, or a body of documents of doubtful authenticity older still by many more centuries. Yet certain well-organized religious denominations still profess to be guided by such creeds and texts and documents. In such profession we find an unfortunate consequence of the very rapid reconciliation of theology and science, because the change of religious thought involved in the reconciliation has taken place so fast that the change of formal expressions of religious belief has not kept pace with it. The laity of such denominations, therefore, find themselves in the dilemma of either sitting under hold-fast conservatives who are as out of date as the creed they have solemnly promised to preach, or under liberalized progressives who have as solemnly promised to preach a creed which they no longer believe; and the worst of it is that the laity are so indifferent to their dilemma that they take no efficient steps to get out of it.

It may, perhaps, be thought that what has been said thus far about the reconciliation of Christian theology and science goes too far. Remember, therefore, that the reconciliation has not been described as by any means complete, but only as rapidly growing and as being in some quarters already far advanced. In support of this conclusion, let me here read some extracts from the above-cited report, "Re-thinking Missions," by a many-denominational Committee of Appraisal. They unanimously agree on the following statement: "Only a religion whose first principles are capable of the simplest formulation can become a religion for the modern man. . . . The religion which assumes too much knowledge of the supernatural realm, its system of heavens and hells, or its inner mechanisms of eternal justice, can no longer be a living issue."

Or again: "Western Christianity has in the main shifted its stress from the negative to the affirmative side of its message; it is less a religion of fear and more a religion of beneficence. It has passed through and beyond the stage of bitter conflict with the scientific consciousness of the race over details of the mode of creation, the age of the earth, the descent of man, miracle and law, to the stage of maturity in which a free religion and a free science become inseparable and complementary elements

in a complete world view. Whatever its present conception of the future life, there is little disposition to believe that sincere and aspiring seekers after God in other religions are to be damned; it has become less concerned in any land to save men from eternal punishment than from the danger of losing the supreme good."

The following passage concerning the larger Christian denominations is also instructive. "They were formed at a time when a precise and definite theological system of doctrine was generally stressed as vitally important, and this theological emphasis has remained up to the present time a dominant feature of these conservative churches. This excessive occupation with theological doctrine has kept such churches out of touch with trends of thought and intellectual problems in the world around them. Churches of this sort appeal only to a certain type of mind. Students in the main leave them coldly alone and are apt to be turned against Christianity if this is the only kind of Christianity which they know. It seems to them too often a complicated religion of words and phrases, dealing with the issues of a former age, not a living force for the moral transformation of the world and for the remaking of the present social order."

Strong support is thus given to the above-stated faith of reverent science, but its various omissions may make it unsatisfying to many devout Christians who, although now standing much lower down on the long flight of theological steps than their grandfathers did, have not yet descended to the foot of the flight They surely have the same right to adopt and maintain their beliefs as we have to form and maintain ours. As long as their beliefs help them to lead good and happy lives, let them be held fast; for in addition to the above-recited articles of the faith of reverent science, there is another: "Give up no belief until it may be replaced by a more helpful one" Thus may be avoided the unhappy fate of those who, over-rigidly brought up, think that the abandonment of their early faith leaves them with none.

Reflections Let us now turn to some reflections on the statement made at the beginning of the address, that all religions are, like all sciences, of human origin, in other words, that religion and science are both examples of the natural evolution of human thought. Note particularly that this does not involve any change in the articles of belief of any religion They stand unchanged. True, the attribution of religious beliefs to human sources may cause a change in the attitude of those believers who are accustomed to taking authority for truth; they may feel differently toward the religion they profess if they come to regard it of human origin. But others who are trained to take truth for authority will not change their attitude; the evidence which had previously convinced them of their religion's verity will still convince them. Dissent from the view that all religions are of human origin will of course be expressed by the conservatives of to-day, just as their grandfathers two generations ago expressed dissent from the view that all plants and animals are examples of the natural evolution of organic forms. The present-day conservatives will urge that at least their own religion is based on supernatural revelation; and the same claim would be made by the conservatives of other races, if the question ever arose among them. The present conservative belief in the supernatural revelation of various religions is therefore a parallel to the orthodox belief of our grandfathers in the supernatural creation of organic species. But this latter belief has

been given up by many intelligent persons in the era of reconciliation. Hence the belief in supernatural revelations as the basis of religions may also be increasingly given up as time passes. It certainly seems to be losing ground at present. What will our grandchildren think about it?

We may here profitably quote again what was said fifty years ago by Bishop Temple, of London, regarding Darwinism. He came to think that it was more fitting for a Supreme Creator "to impress His will once for all on His creation, and to provide for all the countless varieties [of organic forms] by this one impress, than by special acts of creation to be perpetually modifying what he had previously made" This view of organic evolution may be rephrased so as to apply it to religious evolution, as follows: "It is more consistent with the modern understanding of the universe to suppose that moral progress is inherent in human nature, and that all such progress is therefore the result of a continuous natural evolution, than to ascribe it to supernatural revelations, those of later date modifying those of earlier date." Thus rationally interpreted, a new faith would arise when a prophet makes an acceptable modification of an earlier faith. The new faith would first appear in some limited area of the earlier faith; once established there, it would spread as far as it could into larger and larger areas; but as it spreads, new modifications, which we know as sects, would branch off from it; and they in turn would spread as far as they could. The faith of reverent science is one such.

The spread of new species of plants and animals from the areas in which they arise is controlled largely by geographical and climatic factors; the spread of new religious faiths—that is, of new species of belief—appears to be largely determined by racial mentalities, for the greater religions of to-day are rather closely related to the races of man. In view of this parallel between species of organisms and species of religious faith, the natural instead of the supernatural origin of religions may come to be more and more accepted by our children and theirs, just as we have come more and more to accept the natural instead of the supernatural origin of organic species.

How instructive it would be if we could obtain some definite measure of the rate of change of these opinions. A measure might be secured if a good number of churches of various denominations would cooperate, first, in preparing questionnaires on a variety of articles of Christian belief, and second, in asking their members to indicate their opinions of those articles. Replies would probably be of four kinds: Some church members might not have definite beliefs; let them remain in their uncertainty. Others might have definite beliefs but be disinclined to express them; let them remain silent. But the rest, and probably a good majority, would know and be willing to express their views If such a census were taken every five or ten years for a century, we should be able to measure fairly well the drift of religious opinion in the census area. We could then learn something as to the rate at which descent is made from the long flight of theological steps, far up on which our grandfathers stood, and something also of the number of those who have reached the solid ground at the bottom of the flight, where they may hold the faith of reverent science. The value which such censuses would have in the future may be estimated by the value we should attach to them to-day if they had been taken during the last hundred years.

Another reflection concerns the value

that will be placed by future historians on the enormous change of religious beliefs which has been brought about by scientific study during and since the Victorian era. They will look back on this period as one in which many have liberated themselves from the centuries-long enslavement to the crude myths of an ancient and ignorant Asiatic people. The historians will see, as we also may see, in the long period during which the enslavement lasted, a measure of the astounding credulity of the human mind and of its incapacity to think out its problems by a reasonable, scientific method. They will see, as we indeed may see already, that confidence of belief and certainty of conviction do not suffice to prove the objective truth of the opinions so earnestly held. The historians will moreover recall the self-satisfied assurance with which the fathers of the church, while grossly ignorant of the natural world around them, believed they could solve the profoundest mysteries of the supernatural world, and they will contrast that assurance, as we may too, with the increasing mistrust which we moderns feel concerning the supernatural solutions reached by the fathers, in spite of our amazing increase of natural knowledge.

Those future historians will say our liberation from that centuries-long enslavement was tantamount to a declaration of independence, of as great moment in the spiritual world as the declaration of independence, which we Americans made in 1776 was in the political world. But the two declarations are unlike, in that the earlier one was definite in form, place and date, while the later one is indefinite in those dimensions. We can not, therefore, celebrate it by parades and orations and fireworks on a certain date every year, but it is nevertheless worthy of celebration, and I wish to outline a method of celebrating that spiritual declaration in a manner befitting its importance. This is the prognostication mentioned in my introduction.

Prognostication. Our declaration of spiritual independence can be best celebrated by a long festival of cooperation between the organized forces of religion and science—the priesthood and the professorhood—directed to the object which the priesthood has always, but the professorhood has not always held in view; namely, the betterment of humanity; and the festival must be continued into the future at least as long as the period of antagonism which so unhappily divided the two forces in the past. They may be ushered in during an era of brotherly love, vastly more truly Christian than the unhappy medieval era from which we have escaped, and therefore an era of enormous importance in human history; for the festival of cooperation should enlist all those members of the priesthood who, recognizing the victory of modern science over ancient theology, desire to replace a good share of their study of theological apologetics by a scientific study of the nature of modern man and of the methods by which he can be ethically moved; and it should enlist also all those members of the professorhood, who, still preserving their scientific methods but impelled by the faith of reverent science, wish to turn their studies toward humanity rather than to the further investigation of the non-human universe.

Let the attack on all those vast non-human problems be of course continued by such members of the professorhood as are not attracted to human problems; let the attack go on until all the island universes 300,000,000 light-years or more distant shall have been discovered and catalogued; let it go on until the almost infinitely minute electrons have been resolved, if they are composite, into their infinitely more minute constituents, as

atoms have been. Similarly, let all the more conservative members of the priesthood, who do not accept the results of modern science, continue their efforts toward human betterment by orthodox theological means. But it will be from this festival of cooperation, as it is entered into by more and more priestly and professorial members, that we shall expect the greatest progress in bettering humanity. Largely by such cooperation will appropriate scientific methods be applied, more than ever before, to the heavy task on which a theologically dominated religion has labored so long; for on that heavy task, if we may judge by the unscrupulous greed of our growing criminal class, and by the cheap complacency with which a still larger class seems to look upon the successes of the criminals, the long lasting labor has not been expended with great success. How can science *dare* to stand aside any longer, instead of taking a more active part *with* religion in directing its best efforts to the accomplishment of that greatest of all tasks? A reproach has been directed against Nero because he fiddled while Rome was burning. What will our descendants say of us of the professorhood who, assured of our salaries or our pensions, continue to work upon our recondite, non-human problems, while our neighbors suffer and our nation is criminally demoralized.

I am not unmindful of the efforts already made for betterment, nor would I overlook whatever measure of success those efforts have reached. In particular would I recall the historic fact that, even during the era of antagonism between theology and science, efforts for human betterment were made more largely by the priesthood than by the professorhood. Those efforts were, to be sure, guided by what we now consider mistaken beliefs, and they were too often directed by a wish to secure a verbal profession of faith rather than an actual performance of good works; but they had the high merit of being closely associated, all through the Christian era, with correction of error, relief from distress and consolation in affliction, as they are still. But as far as efforts of the priesthood toward ethical betterment are concerned, they have been, as a rule, too narrowly limited to precept and exhortation, without a sufficient use of what would, in scientific teaching, be called laboratory exercises. It is for that reason that we may have confidence in the attainment of a greater measure of ethical success in the future, when our efforts toward that end are guided less by theological than by scientific principles; and when those better guided efforts are applied not only through exhortation to the young people who go to church on Sunday, but also in a more practical manner to the larger numbers of them at school and college all through the week. A great change must therefore be made in our educational methods during the festival of cooperation. There was a time not long ago when the heads of colleges were, almost as a matter of course, chosen from the priesthood; and when the morals of the students were cared for by the required attendance at morning prayers every day and at church services once or twice every Sunday; in other words, morals were then taught by precept. That was a time when physics and chemistry, botany and zoology were also taught by precept. We have now come to a time when the heads of colleges are seldom drawn from the priesthood but more generally from the professorhood; and when the sciences are increasingly taught by laboratory exercises, in which actual performance is required of every student. Yet in spite of these scientific advances, *less* rather than *more* attention is now given in colleges to the inculcation of morals, perhaps because of an increasing consciousness that the old

method of inculcating them by precept was so ineffective. To be sure, elective courses are offered in ethics; but they are not very largely taken and they treat chiefly the ethics of peoples and races; or if individuals are mentioned they are usually famous persons, not mere boys who call themselves *men.*

This inattention to the local individual must be corrected. Just as physical health and bodily strength are increasingly secured for each student by the performance of appropriate bodily exercises in gymnasiums or on playgrounds, so ethical health and the building of finer characters must in the future be secured by the performance of appropriate exercises in what may come to be called an ethical laboratory; and such exercises will gradually penetrate downward from the colleges where they are developed into the schools. There is today a not unnatural unwillingness to have any one religious faith taught in the schools; there will be no such unwillingness shown regarding the practical inculcation of ethical principles, for ethical principles are substantially alike in all the religions professed amongst us.

But it is not only by downward penetration from colleges into schools that better methods of ethical education will be extended. They may also penetrate upward from schools into colleges. The efforts of an important movement, already developed among school-teachers and known as "progressive education," are directed toward discovering the best means not only of teaching children but of developing their finer qualities. What career, therefore, can be nobler than one in which men and women of real ability are thus not instructing children only in the rudiments of knowledge but are developing their loyalty to high ideals; for in that career those consecrated to it are not merely *earning* a *living* out of teaching, but are *spending* their *lives* on it. The discouragements in work of this kind will be many; assured successes will be long delayed and few. No immediate and definitive results, such as those which commonly attend investigations in physics and chemistry, are to be expected. Experiments in human betterment must last a lifetime Hence only those of the professorhood should undertake betterment problems who desire, as the best of the priesthood have for centuries desired, to consecrate their lives to a task of uncertain rewards, yet a task on which the future of humanity must largely depend.

This proposed festival of cooperation may perhaps be decried as absurd, and its practical exercises in ethics may be deemed fantastic by doubting Thomases; but the cooperation is eminently feasible, and the practical exercises in ethics can and must be developed. Nowhere are they more needed than by the rising generation in our own country, where the lawless greed which so abounds in the grown-up generation excites astonishment, to say the least, among our friends in Europe, while our own inefficiency in correcting lawlessness, not to say our indifference to it, mortifies us so profoundly at home; for we are living in an era when professional politicians are increasingly governing us to their selfish satisfaction and to our disgrace, and when organized criminals, ingeniously sheltered from the law by expert legal advice, are to our shame conducting a more profitable business than any one else. We must surely during the festival of cooperation make a vastly more active and effective educational effort toward ethical betterment than we are now doing.

Our universities must come to recognize the need of such effort. They have grown enormously in the last century. Opportunity for study within them has been immensely broadened by enlarging

the equipment of faculties, laboratories and libraries. Direction and supervision of study is so much improved that scholarship has risen gratifyingly in spite of the many distractions that tend to lower it. Let the next step in advance be that of character-building. Let courses in practical ethics be introduced, tentatively at first, with more confidence later on. Perhaps some such courses are already established, but they are not yet usual, as they must come to be.

Imagine a general introductory course of 100 or more students. At its close let the professor in charge invite a promising group of its members to go on with him for another year in an avowedly experimental course, in which all shall agree to study each other, all to estimate the strength of various ethical qualities possessed by each, and then jointly to devise practical exercises which shall strengthen the weaker qualities. Something valuable would surely be learned after ten or twenty years of such experimentation in ten or twenty colleges; and from that beginning further steps might be taken. For remember, our festival of cooperation is to go on for centuries. When the planning of these exercises is under discussion, all persons should be excluded who say at the beginning that such exercises can not be successful. Plans should be made only by those who insist that at least some exercises *can* be and *shall* be successful. Above all, let no one say, "Human nature can not be changed." It has already been enormously changed and it is going to be changed more still. Every ardent disciple of Christ must believe that. Could any university president have a higher ambition than to see, during his administration, the successful development of wholesome courses on character-building, as a fitting supplement to the broadening of opportunity and the raising of scholarship by his predecessors?

Mistakes will be made, of course, but mistakes can and will be corrected. The most manifest will be the development of self-conscious priggishness; that must be avoided by the cultivation of a truly Christian humility It is already known that profitable elementary exercises in ethics may be introduced unconsciously in games and sports; witness the expression, "It isn't cricket," by which meanness and under-handedness are condemned in England, the home-land of fair play. We may build much farther on that beginning. Let the ability, the inventiveness, the perseverance which have characterized progress in non-human sciences be applied practically in ethical science and it will then advance as it never has yet; but it must not be expected that the advance will be rapid. No one may know to-day the most effective methods of forming habits of self-control and self-sacrifice, up to a truly Christian standard; but better methods will surely be discovered by scientific study and experimentation. Such study may even teach us how to do unto others as we would that others should do unto us; and when we learn how, let us call that great principle "the rule of unselfish happiness," not the "golden rule." Golden is not a good enough name for it.

The development of school and college courses in practical ethics should not, however, be by any means the only object of the festival of cooperation The festival should be so conducted that it will attract large endowments for the investigation of the best methods of advancing human betterment, in order to aid in the development of school and college courses. We have such endowments already for various objects of a somewhat like nature. One of them is endeavoring to stamp out certain diseases at their source. Several endowments are studying the means of pro-

moting public health. We have various excellent organizations for practical betterment, such as eugenic societies, institutes of family relations, and so on. Some investigators are striving to discover the cause and cure of cancer. But most of these are working collectively on the human body; few are working on individual human natures. May we not therefore hope that future endowments shall be more directly applied to the discovery and cure of the mental disorder known as selfishness, which lies at the very root of so many of our disorders. Surely that mean and degrading quality is more damaging to humanity than cancer is! The wonder should be that a concerted, scientific attack on it has not been already made. Is the delay perhaps due to an aloofness of the professorhood because of a semi-conscious but mistaken feeling that the correction of moral faults is the business of the priesthood? If so, let us hope that the mistake will be soon corrected; not that the priesthood shall cease their efforts but that the professorhood shall helpfully cooperate with them. How wholesome it will be to bury the acrimonious disputes which separated those two great forces in the past, under the cordial relations of the future. Can there possibly be a nobler crusade than one formed by the union of those forces marching unitedly against the defects of humanity? If our defects are due to our glands, then let the crusade march against the glands!

But let it be understood that the crusade is not to be begun by proclamations calling attention either to it or to its object. It will begin inconspicuously; it has undoubtedly begun already in various quarters. But it is at present everybody's and therefore nobody's business. What it now needs is organization and direction; and it is in supplying that need that a long-lasting endowment for coordination will be immensely useful; an endowment directed by men of constructive and persuasive wisdom, who would give their whole time to it and who would, for years and years to come, encourage and focus on a central object the many lines of religious and scientific effort which are now pursued too independently for the greatest efficiency. Can this association, which is pledged to the advancement of science, possibly do better work than promote the establishment of such an endowment? Is there anything in the world more important and more difficult to work upon than the improvement of human nature? Can science anywhere find a more worthy subject for investigation than the methods of accomplishing such improvement? As an encouragement to persevere against difficulties, let us remember again that we live in a world which was merciless for ages and ages, but a world in which the quality of mercy was developed, not many centuries ago, by unconscious evolution; a world in which a sense of justice has similarly arisen, telling us that might is no longer right, although it truly used to be right. If so much has been gained by unconscious evolution in the last few thousand years, how much more may we hope to gain from conscious evolution during the plenitude of time to come!

Reference to science has often been made in this address. Let us be careful to understand that there is no mystery or magic about it, in spite of its enormous power. Science is merely *well-attested knowledge*. Let no one make the mistake of imagining that it is hard or unfeeling. In tasks where vigorous action is needed, it works with active vigor; in those which call for gentle sympathy, it is gentle and sympathetic. Its faithful handmaid, logic, will be deemed cold only by those who like to repose on mossy banks of outgrown beliefs in shady groves of tradition, for

naturally enough such slumberers do not wish their repose disturbed by the clear light of truth. The fields of science include everything that can be observed; for example, human conduct: human conduct being merely one of the many problems which finds a better explanation under the scientific philosophy of natural evolution than under the credulous theology of supernatural creation. The results of science are not final or absolute; they are always open to correction and extension. The essence of its spirit is a search for truth, by which, as an old philosopher long ago said, *no man has ever yet been harmed*. That search has been wonderfully successful in the physical world. Great renown has come to members of the professorhood through their discoveries, even if what they have discovered is as utterly remote, as utterly beyond application to the betterment of humanity as the dimensions of the orbits of a binary stellar system, the two members of which have never been seen apart even in the most powerful telescopes. True, such discoveries *do* teach us more of the mystery of the universe as well as of the possibilities of achievement by the human mind; but unfortunately, the privileged few who have the time and the ability to achieve such discoveries and to appreciate their meaning constitute almost a secret order, far above and regrettably apart from the ordinary run of mankind. By all means let those distinguished members of the great professorhood go on and discover new marvels in the physical world and the astronomical universe, but may we not hope to see, alongside of them and equally honored with them, another group of the professorhood who shall apply themselves with equal ability and assiduity, and in harmonious cooperation with a liberalized and growing group of the priesthood, to solving the everyday terrestrial problems of selfish humanity? Many difficulties lie ahead. Progress will be slow at best. But surely we may look forward with confidence to bettering days when our festival of cooperation is well under way. For my own part, and I trust for many others also, the ground for that forward-looking confidence is an optimism which is based on a study of the past and which springs from a firm belief in the philosophy of evolution and the faith of reverent science.

ON THE ABILITY OF WARM-BLOODED ANIMALS TO SURVIVE WITHOUT BREATHING

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THE need for oxygen is the most insistent requirement for human life. It is quite different from the requirements of food and water, which need satisfaction only at intervals which may be quite prolonged without discomfort. If man is deprived of oxygen for a minute his situation becomes quite intolerable, and if the period of deprivation is only slightly extended consciousness is lost and life soon ends The brevity of duration of life without oxygen leaves only a narrow margin of oxygen reserve to separate life from death.

This narrow margin of oxygen reserve between life and death has been of great importance in determining human activities and behavior. The usual termination of life comes as the result of interruption of respiratory activity. Only one link in the chain of processes which secure the continuity of respiration need be broken, and the processes by which respiration is effected are delicate. The peril of death is always imminent from the disturbance of respiratory functions, and the preservation of respiratory activity is secured by giving precedence to its reflex control. If respiration is forcibly arrested, the most violent of all possible physical struggles ensue, at first directed toward relief of the obstruction, but rapidly becoming incoordinate. Even a decapitated animal which has been kept alive by artificial ventilation shows violent though incoordinated struggles upon cessation of oxygen supply. It is no exaggeration to say that the matter of securing a constant and adequate supply of oxygen is a constant preoccupation during life.

The period during which man can suspend respiration has influenced many of his separate activities. It must be allowed for in musical notation and determines the length of spoken phrases. Respiratory movements interfere with the most delicate manipulations and may be voluntarily restricted for a short time. Restraint of respiratory movement is likewise a condition for extreme attention to the perception of faint odors or sounds. It is also the respiratory requirement which restricts the ability of man to be submerged, and sets the limits of time and depth to his natural means of submarine exploration.

Most warm-blooded animals resemble man in the shortness of the time for which they can remain submerged, and yet there are certain diving animals which notably excel the ordinary terrestrial forms. These diving animals are not restricted to a single small group, but appear among several orders of birds. Among mammals, besides the aquatic manatees, whales and seals, there are, for example, the muskrat and beaver, the hippopotamus and the otter.

In order to examine the proposition of what limits the ability of man for submergence and what apparently extends that ability in certain other animals, we can begin to examine the capacity of man.

If respiration is temporarily arrested, the period for which any one of us can hold his breath without extreme discomfort is limited to forty-five seconds. If, however, some previous preparation is made by forced deep breathing, that period may be extended to five or six minutes. If to that preliminary period of deep breathing is added the respiration of oxygen, the time may be ex-

tended to a total of 10 or 15 minutes. The latter device was made use of in the preparation of sprint swimmers in the recent Olympic games and gave to the users a distinct advantage on account of longer freedom from the necessity for respiration.

The rate of oxygen consumption is one factor which determines the period during which a man can hold his breath For a person at rest we can take the oxygen consumption to be 250 ccm per minute; with only quite moderate activity, such as walking, 7–800 ccm per minute are required. For heavy work, such as mountain climbing or other violent exercise, the consumption may rise to from 1,500 to 2,000 cc per minute. A Marathon runner traveling at seventeen kilometers per hour consumed as much as 3,500 ccm per minute [1]

Against this demand we find that the ordinary individual has certain capacities for the storage of oxygen. Storage in the lungs is the most obvious reserve. This so-called "vital capacity" amounts to about 10 per cent. of the body weight; 70 kilograms body weight would thus contain 7 liters of air. Of the 7 liters of air, about one fifth would be oxygen and would afford about 1,400 ccm of oxygen. Furthermore, a certain amount of oxygen would be stored in the blood. Allowing approximately 7 per cent. of the body weight as made up of blood, with an average oxygen content of 17 ccm per 100 ccm of blood, we find that the total quantity of oxygen in the blood would be about 830 ccm.

In addition to these more apparent stores of oxygen, there are other body fluids which are more or less saturated with oxygen. The degree of oxygen saturation of the tissue fluids is a matter of some doubt, but it can scarcely be greater than one half, and the corresponding quantity of dissolved oxygen would be about 600 ccm.

These three reservoirs of oxygen in the human body together provide a maximum store of less than three liters. Actually it is quite impossible that the entire quantity would be available for use; for there must always be maintained a certain gradient which serves to force the oxygen from the places where it is stored into muscles and other tissues, where it is to be consumed. Probably not more than one half the total stored oxygen would be available for use when respiration was arrested. This would amount to about 1,500 ccm. Since the oxygen requirement at rest is 250 ccm. per minute, the reserve would seem to allow for survival at rest without a new oxygen supply for as much as 6 minutes. That is just about the period of survival if the oxygen consumption is maintained at the low resting level by anesthesia. Beyond that time the flame of human life is low and uncertain.

It is also true that, in addition to the store of oxygen that is dissolved in tissues and blood, there exists an important mechanism which is capable of maintaining the muscle tissues during a period when oxygen is not available. It depends upon the ability of the muscles to transform glycogen into lactic acid without the intervention of oxygen in the process. The reaction yields energy which can be applied to carry on muscular activity. At the expense of the glycolytic reaction, muscular activity can be accelerated far more rapidly than the processes which supply the muscles with oxygen. The limit is soon reached, however, and before complete recovery occurs the products of glycolysis can only be restored by the use of extra oxygen. For this reason, the processes of brief intense muscular activity develop an oxygen requirement in the body which is designated as an oxygen debt. It is not, however, like a national debt, for it has precise limits and must be repaid in terms identical to those under which it was incurred.

The repayment of the oxygen debt is indicated by an extra consumption of

[1] F. A. Bainbridge, "The Physiology of Muscular Exercise." London, 1931.

oxygen during the recovery, and it is measured in terms of this extra oxygen consumed. For a trained athlete such as a sprinter the debt may amount to as much as 15 liters of oxygen,[2] and it indicates the existence of an energy reserve for muscular activity equivalent to the energy which would be derived from the utilization of 15 liters of oxygen.

In contrast to the total stored oxygen of 3 liters, 15 liters is quite a large amount, and one would be inclined to turn to this device in order to provide means of survival when respiration is arrested. But this method of metabolism is, as far as we know, available only for muscular activity and is not extensively utilized by any other tissue than muscle. So that while the oxygen debt may serve very well to carry on muscular activity during a short period of asphyxia, it does not solve the problem of an energy supply for the other tissues. Perhaps it is on account of the lack of means to develop an oxygen debt that the heart and brain are particularly susceptible to asphyxia.

The various means which have been proposed are not capable of maintaining survival during extended periods of asphyxia, and we can scarcely see how it would be possible for a human animal to survive for more than a few minutes. Many animals, on the other hand, are superior to man in this respect. Probably the first systematic work on this subject was done some years ago by Paul Bert.[3] He determined the period during which a number of animals survived forced submergence under water. Various terrestrial animals, such as the dog, cat and hen, survived submergence for from 2 to 4 minutes. Similar examination of animals with a partly aquatic habitat, such as gulls, indicated that they were not superior to the terrestrial animals. But the ordinary domestic duck, not a highly developed nor actively aquatic animal, survived for a period of 10 to 15 minutes; a young seal (remarked upon as not in very good condition) was still moving at the end of 15 minutes, and the heart continued to beat for 28 minutes.

It is of interest to consider the further observations of Paul Bert on the marked ability of young animals to survive asphyxia. New-born rats would survive thirty minutes; for adults the limit of survival was about two minutes. During development the period which they survived progressively diminished. This remarkable capacity for resistance to asphyxiation in new-born animals he related to the necessity for sudden development at birth from a condition in which the respiratory apparatus had not been in use. During the time of birth in mammals there must occur a more or less prolonged period when respiration is quite impossible. Respiration then starts rather hesitantly and only after some time does it become regularly and firmly established, and during its earliest life the young mammal can easily endure asphyxia for periods which would later be fatal.

The experiments on forced submersion would appear to be rather artificial and would scarcely give the animal a fair chance to demonstrate its full ability to endure asphyxia. On looking through the literature to ascertain the opinion of the various authors on the duration of the period for which diving animals can remain submerged voluntarily, we find that good observations are scarce. Leonard Hill[4] has said that the human limit was probably that of a pearl diver, amounting to about 3 to 4 minutes, without any previous oxygen treatment. The record period he claimed for a skilled diver, who remained submerged and visible in a tank for nearly five

[2] *Ibid.*

[3] Paul Bert, "Leçons sur la Physiologie Comparée de la Respiration." Paris, 1870.

[4] L. Hill, "Caisson Sickness and the Physiology of Work in Compressed Air," pp. 8–16. London, 1912.

minutes. Professor Parker[5] observed the respiratory periods of the Florida manatee in an aquarium, and the longest interval between respirations was 16 minutes and 20 seconds.

Beyond these few observations we find what seems a singular hesitation on the part of naturalists to state how long a diving animal can or even does submerge. The beaver can swim under water for about five minutes, according to Ernest Thompson Seton's[6] calculation from the statements of the old trappers. The ability of diving birds has probably been overrated on account of their skill at concealment when emerging. Mr. Arthur H. Norton, curator of the Portland Society of Natural History, sent me a number of observations, and the longest records were those of the loon and old squaw, with about 40 seconds' submergence. And yet the Great Lakes fishermen tell of old squaws caught in nets at the depth of 180 feet (according to a communication from Dr. Remington Kellogg), and there are stories of the capture of loons on set lines at considerable depths.

It seems singular that observations of so interesting and important a nature are not more frequent. Trappers and guides, who live by keen and accurate observation of wild animals, will scarcely venture an absolute opinion on the subject, and reserve their comments for those times in camp when the vivid interest of a story takes precedence over the limitations of truth.

For over two centuries seals and whales have been systematically hunted, and the accounts of the pursuit quite properly form an extensive and fascinating literature. But as a consequence of the difficult conditions for observation and the romantic flavor which is so easily attached to whaling stories, we find that reliable authors show a good deal of hesitation in committing themselves as to just how long a whale can remain submerged. The longest story which I have encountered attributes to the Rorquals the ability to remain submerged for from eight to twelve hours.[7] Among the accounts of more cautious naturalists who have actually timed the dives, I find the observations listed in Table 1, that indicate the duration of submergence which the authors have actually observed and the longer periods, which, in the opinion of whalers, seem to be within reason.

The most interesting description of the ability of a whale is that of Captain David Gray,[8] commander of the whaling steamer *Eclipse*, in a description of the

TABLE 1

PERIODS OF SUBMERGENCE OF WHALES

Kind	Diving periods: observed	Diving periods: from opinions	Author
Humpback	20 min.		Andrews[9]
Finback	23 "		1909
New Zealand Humpback	7 "	1 to 2 hours	Lillie[10] 1910
Fin whale	20 "	45 min.	Ommanney[11] 1932
Finback	10 "		Allen[12] 1909
Bottle nose	2 hours		Gray[13] 1882
Sperm		1½ hrs.	Beddard[14] 1900
Greenland right whale	1 hour 20 min.		Scammon (from Beddard 1900)

[5] G. H. Parker, *Jour. Mammalogy*, iii: 127, 1922.

[6] E. T. Seton, "Life Histories of Northern Mammals," i, 475. New York, 1909.

[7] R. Collett, *Proc. Zool. Soc. London*, p. 263, 1886.

[8] D. Gray, *Proc. Zool. Soc. London*, p. 726, 1882.

[9] R. C. Andrews, *Bull. Am. Museum Nat. Hist.*, xxvi: 213, 1909.

[10] D. G. Lillie, *Brit. Mus. Nat. Hist. Reports*, British Antarctic (Terra Nova) Expedition. Vol. i: part 3, 1910.

[11] F. D. Ommaney, Discovery Reports, v: 327, 1932.

[12] G. M. Allen, *Memoirs Boston Soc. Nat. Hist.*, Vol. viii: No. 2, 1916.

[13] *Op. cit.*

[14] F. E. Beddard, "A Book of Whales." London, 1900.

bottle nose whale presented to the Zoological Society of London.

> They have great endurance, and are very difficult to kill, seldom taking out less than three to four hundred fathoms of line; and strong full-grown males will run out 700 fathoms, remaining under water for the long period of two hours, coming to the surface again as fresh as if they had never been away; and if they are relieved of the weight by the lines being hauled in off them before they receive a second harpoon and a well-placed lance or two, it often takes hours to kill them. They never die without a hard struggle, lashing the sea white about them, leaping out of the water, striking the boats with their tails, running against them with their heads, and sometimes staving the planks in, frequently towing two heavy whale-boats about after them with great rapidity.

From these various accounts we can conclude that certain mammals have a capacity to resist asphyxia which far exceeds the ability of man, and, as a matter of fact, exceeds the capacity which we would expect on the basis of the amount of oxygen stored. That being the case, then, we might consider what modifications occur in these animals which would adapt them to survival. One might be an increased vital capacity with an increase of oxygen stored in the lungs. This capacity might possibly be doubled; on the other hand, if it were to be much more than doubled there would hardly be space available in the body to accommodate the other organs. Birds in particular have a very extensive respiratory apparatus, but when Mr. Foster and I examined the vital capacity of the duck, we found that it was only about double that which would be expected in a mammal of the same size. The hen has nearly as great a vital capacity as the duck, and yet is quite inferior even to most mammals in ability to resist asphyxia. Even doubling the vital capacity stores only sufficient oxygen for another minute or two of resting metabolism. So it is not possible to account for the superior ability of diving animals by greater air storage.

An increase in the volume of blood might be considered. Many authors have called attention to the peculiar vascular devices common among aquatic animals, the *retia miriabilia* or networks of blood vessels, which are often quite extensive and which would seem to give to the animal a greater capacity for blood and hence for oxygen storage in the blood. By determination of the blood volume by means of vital red injection Mr. Foster and I found that the blood volume of the duck and muskrat were about 10 per cent., somewhat greater than is usually found for mammals. But again the hen was nearly as well provided with blood.

It is unlikely that vital capacity and blood volume could both be doubled, for they would then occupy some 35 per cent. of the body, scarcely leaving room for the other organs. Even such an increase would only provide the capacity for a few minutes' longer survival without respiration. If, then, we could give the animal only a slight addition to its ability to survive, making the limit three or four minutes instead of one or two, it would not seem worth while to consider these modifications in the respiratory or circulatory system as sufficient to adapt an animal like the whale to attain its great ability for submergence and under-water activity.

We should also consider the possibility of increasing the capacity for muscular oxygen debt. That seems at first sight a tempting possibility to investigate. But an increased capacity for developing an oxygen debt implies a superior buffering capacity in the muscles. To postulate a large variation in such a fundamental chemical property of muscle is rather dangerous, for we know that the principal chemical properties of all vertebrate muscle are essentially alike. As an indication of buffering capacity of the muscle, we have examined the carbon dioxide content of the muscle of ducks and muskrats, and found them

similar to the muscles of cats and dogs. Furthermore, if we were to increase the oxygen debt forming capacity, it would only influence the capacity for maintaining muscular activity for a longer period of time. It would not help the heart and brain to survive.

I do not think that the difficulties of non-diving animals rest in the preservation of the skeletal muscles; the oxygen supply for an arm or leg may be cut off for from 10 to 15 minutes without discomfort, and for much longer than that without actual injury to the part. More difficulty seems to arise in protecting the more sensitive tissues, such as the heart and brain, which are so sensitive to asphyxia

It often happens that when we examine an animal part by part and then attempt to recreate the whole by the addition of parts, we find that the whole animal is quite different from the sum of its component parts. There are certain relations according to which the parts are made to cooperate, a peculiar type of integration which completes the working organism in a manner which is not by the simple addition of functions. The mechanism for the control of this integration we regard as the central nervous system. Perhaps we are likely to call it behavior, if we are of one type of biologist, or, examining the process as physiologists, we are inclined to analyze this behavior into its component parts, and refer to them as reflexes. It seems possible that it might be pertinent to examine some of the reflexes of diving animals to see whether they may be responsible for some degree of protection against asphyxia.

The first definite information which appeared was published again by Paul Bert[15] on the behavior of ducks when forcibly immersed in water. They remained quiet and passively endured asphyxia for from 12 to 15 minutes. This behavior is quite in contrast to that of terrestrial animals, which, when submerged, or when the trachea is clamped, immediately perform convulsive movements which violently attempt to relieve the animal from the cause of asphyxiation. The movements soon become quite purposeless and actually serve to accelerate exhaustion and death. The duck, on the other hand, conserves its energy by eliminating all muscular activity.

The process of inhibiting muscular activity has been definitely worked out as a reflex reaction, aroused by postural stimuli which give the inhibition even when the animal is out of water.[16] By holding the head and neck of a duck in a certain position, resembling the one assumed when under water, that is, with the head and neck extended and slightly depressed, all activity of the animal ceases. The same sort of reflex inhibition of muscular activity can also be seen in the muskrat under a stimulus of the same kind. Activity of the respiratory muscles is inhibited as well, and respiratory movements are at once abandoned. A duck or muskrat can be held in that position for several minutes and no attempt to breathe will be made. That type of reflex is obviously of an adaptive nature in conserving the energy of animals for existence under water.

Along with the depression of muscular activity and the cessation of the working of the respiratory system, the following significant observation was made by Richet.[17] Inhibition and retardation of the heart beat occurred by stimuli transmitted through the vagus nerve. When the vagus nerve in a duck was cut or inhibited with atropine it survived no longer than a hen would under the same conditions. This reflex mechanism then has a definite conservative

[15] *Op. cit.*

[16] F. M. Huxley, *Quart. Jour. of Exp. Physiol.*, vi: 183, 1913.

[17] C. Richet, *Jour. de physiol. et de pathol. gén.*, i: 641, 1899.

effect in protecting an animal during diving.

Even so, while it may inhibit the activity of the animal, it can not abolish its basal metabolic requirements, and we are still faced with the problem of how these animals survive for as long a period of time as they do. A hint comes from the observations of Gratiolet,[18] who described the vascular structure of the hippopotamus He claimed that there was a muscular band which passed around the vena cava about where it went through the diaphragm. He believed that it had the ability to contract and to prevent the remainder of the blood from passing into the heart from the posterior circulation. He thought that such a mechanism would be useful in preventing the engorgement of the heart and brain which were supposed to occur in asphyxia. The idea of "engorgement," however, may be injected into consideration by reason of subjective sensations during asphyxia, when the cerebral vessels seem to be engorged and the heart feels full; but it is doubtful whether the blood pressure is actually elevated in these organs. On the other hand, if such a device were to shut off a large part of the returning systemic circulation, then it would be possible for such oxygen as was stored in the lungs and blood to be utilized by those organs which are particularly sensitive to oxygen want The muscular tissues could get along with the help of the oxygen debt process, but the heart and brain require some device to aid them.

In recent years more and more attention has been paid to the cerebral and coronary circulations, with the result that it is apparent that control of those systems is quite distinct from the type of control exerted over the ordinary systemic circulation. We find suggestions of this in the apparently opposite action of histamine and adrenalin on coronary circulation. We learn further, from Lenox and Gibbs,[19] that if carbon dioxide is administered to the extent of from 5 to 10 per cent., and the cerebral circulation is judged by the amount of oxygen in the blood returning through the jugular vein, its circulation will be accelerated by as much as 40 per cent., while the circulation through the femoral vein is diminished There is then a relation between the cerebral and systemic circulation, which under conditions of asphyxiation may serve to conserve the blood and oxygen supply for the more sensitive tissues at the expense of the others.

I feel that when we can find neither chemical nor physical processes in the avian or mammal body which would adapt them for submergence, that we should turn our attention to reflex adjustments. It might be pointed out that the physical and chemical properties of the muscles of mammals and of all vertebrates are remarkably alike; the blood apparently has the same characteristics in all forms, and the elements of the nervous system are so similar as to be practically indistinguishable. So we might remark that during the operation of the forces of evolution the physical and chemical characteristics have remained relatively fixed, maintained in an apparently rigid mold. On the other hand, the adaptation of various groups to different environments indicates a remarkable degree of plasticity in the nervous system. In the integration for use of these essentially similar organs arises the capacity for adaptation.

[18] M. P. Gratiolet, C. R. Acad. Sci., Paris, li: 524, 1860.

[19] W. G. Lennox and E. L. Gibbs, *Jour. Clin. Invest.*, xi: 1155, 1932.

A STORY OF THE SHRIMP INDUSTRY[1]

By ELMER HIGGINS

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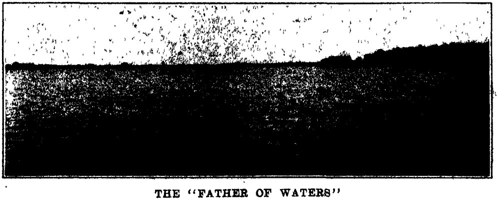
SYMBOLIC of the diminutive and the trivial as an individual, the shrimp as a tribe are far from inconsequential, for the three important species taken from North Carolina to Texas have yielded an annual catch valued to the fishermen in a raw unprocessed state at nearly four and a half million dollars. As a source of food, whether served as the familiar cocktail or as salad or in such marvelous concoctions as à la Creole or jambalaya, the shrimp rivals the sacred cod or the mackerel of the North Atlantic, is half again as productive as the tunas or all the flounders, yields twice as much as the Pacific halibut and eight times as much as the lobster. As a matter of record, in 1929 the shrimp fishery ranked ninth in volume but fifth in value among all the fisheries of the United States. In fact, if all the little shrimp caught in that year were placed head to tail in a straight line, it would take a lot of work. And a lot of work was performed in the 69 canneries of the South, where 1,371,502,720 individual shrimp (or thereabouts) were headed by hand and canned into 818,491 standard cases worth $4,960,542 00, according to the government's published statistics (1930).

[1] Published by permission of the Commissioner of Fisheries.

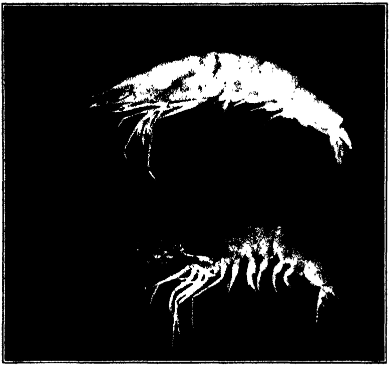
Although I had seen something of the shrimp industry in the South, I now feel that I have made almost personal acquaintance of a good many million individual shrimp after viewing acres of them on drying platforms and seeing tons of them unloaded at canneries during the first days of the autumn fishing season in Louisiana I have recently returned from a trip through the heart of shrimp land—from New Orleans to the Gulf through Barataria Bay—for Louisiana produces 45 per cent of all the shrimp taken on the South Atlantic and Gulf coasts, which in turn is 95 per cent. of the production of the entire country.

I arrived in New Orleans with the intention of reviewing the program of research upon the shrimp and the shrimp industry undertaken cooperatively in the interest of conservation by the U. S Bureau of Fisheries and the Louisiana Department of Conservation. As a part



THE "FATHER OF WATERS"

IN NORMAL STAGES IS SO BROAD AND PLACID BELOW NEW ORLEANS THAT, AFTER THE FIRST THRILL OF MEETING, IT BECOMES AS UNINTERESTING AS A BRACKISH WATER COASTAL SOUND.



SHRIMP OF THE GULF AND SOUTH ATLANTIC COAST

Penaeus setiferus, THE COMMON SHRIMP OR LAKE SHRIMP OF THE GULF AND THE SHRIMP OR PRAWN OF THE SOUTH ATLANTIC, YIELDS 95 PER CENT. OF THE TOTAL CATCH OF SHRIMP OF THE REGION. TWO OTHER SPECIES ENTER THE COMMERCIAL CATCH IN VARYING QUANTITIES. PHOTO BY J. N. GOWANLOCH.

of this review I had planned to observe fully all the various activities, including those performed at sea by the investigative staff. So it was that I spent two days in conferences with state officials and the federal bureau's staff—spent them a little impatiently anticipating the sea trip aboard the bureau's research vessel, *Black Mallard*.

By this time, the captain had the *Black Mallard* ready for us and well provisioned for the run down river to Southwest Pass, so we left on Friday afternoon for an uneventful run on the broad breast of "Old Man River" through a golden sunset to Pilot Town, where we spent the night aboard and started early the next morning for the pass. Trawling for shrimp was to be done in East Bay, a wide expanse of shallow water enclosed between the outspread arms of low-diked river mouths, but stormy weather threatened to disrupt our plans. A brisk southeast wind on Saturday morning whipped the surface of East Bay into foamy whitecaps, making it impossible to work with fragile silk nets searching for baby shrimp. Finally a Coast Guard radiogram received at Burrwood, warning of the approaching Gulf hurricane that ten hours later swept Galveston, convinced the captain of the futility of waiting for the wind to lay, so we put about and retraced our course a hundred miles up the winding river channel to New Orleans in order to reach the gulf and sheltered Barataria Bay by another route.

The return trip was also uneventful,

but it gave our scientific personnel an excellent opportunity to discuss length frequencies, growth rates, appearances and disappearances of the shrimp, water temperatures, salinities and hydrogen-ion concentrations, and all the other voluminous data that are part and parcel of a scientific study of the life history of the shrimp Between such sessions we idly watched heavy-winged white herons rise from the river bank ahead of us, straighten their long legs and flap slowly up river to alight at the water's edge and await our approach only to repeat this senseless retreat again and again.

After spending the night in the mouth of a shallow canal, well screened from singing mosquitoes, we continued our run again early Sunday morning. Finally the low roofs of scattered farm-houses nestled behind the unending levees gave place to docks and factories with tall stacks as we approached the city, and we entered Harvey canal beside the bigger and better locks that will replace the ancient ones now holding back the river when in flood stages

Running down the canal past the Hero pumping plant, which drains the surrounding country, dodging in and out between slow-moving barges, we entered a section of Louisiana filled with romantic legend and haunting beauty, and traversed winding Bayou Barataria southward toward the Gulf. As we passed, brown water from the swamp sucked and whirled among the buttressed trunks of majestic cypress or spreading live-oaks, festooned with garlands of Spanish moss, and over the green wall of the bordering forest glistened towering thunder-heads, portending dashes of summer rain. Past solitary cabins of the moss gatherers, past the scattered hamlet of Barataria we slipped and viewed the village reputed to be the rendezvous of Louisiana's Robin Hood, the pirate LaFitte. Here we encountered solid meadows of floating water hyacinth, blue-flowered and lovely. They are cordially hated by the watermen because they grow so dense as seriously to impede navigation For an hour we plowed through the "lilies," not yet destroyed by the U. S. Engineer's poison sprays, making only four miles; and so dense at times were the waxy leaves and air bulbs that one of our party in a spirit

A LIKELY NURSERY GROUND

HERE WHERE FOREST AND MARSH MEET MAY BE AN IMPORTANT NURSERY GROUND FOR THE LOUISIANA SHRIMP SUPPLY.

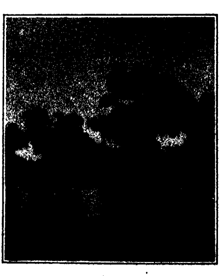
CYPRESS SWAMPS

BORDER BAYOU BARATARIA EN ROUTE TO THE GULF. SINCE EARLY TIMES MOSS PICKERS LIVING IN ISOLATED CABINS THROUGH THE SWAMPS OF LOUISIANA HAVE GATHERED SPANISH MOSS FOR MANUFACTURE INTO MATTRESS FILLERS. ON THE GULF COAST THE ANNUAL CROP BRINGS TWO AND A HALF TO THREE MILLION DOLLARS.

of bravado jumped overboard and walked about on the masses under our bows. Threading Dupré Cutoff, where stand occasional patches of "Ghost Forest," stark and naked trees killed by occasional invasions of salt water in times of unusual drought, we met the marshes, empty stretches of waving saw-edged grass lying lonely and desolate. These are the quaking prairies—"praire tremblante" where beneath one's feet the matted and rotting vegetation trembles on the sodden silty undersoil. Here muskrats build their homes, water-fowl nest and even occasional 'gators lurk. Pressing on, we entered the broad and winding marsh-bordered Bayou St. Denis and sighted the row of beacons in Barataria Bay which we must round before heading for the lights of Manila Village, our anchorage for the night.

After two and a half days of steady running with long hours for the vessel's crew, Monday, which was to be a work day for the scientific staff as well, dawned pink and opalescent upon a glassy bay. We were off early, running southward toward the entrance to the Gulf of Mexico Manila Village and Cabanash, huddles of red buildings perched on piles above the marsh and surrounded by wide platforms for drying shrimp, were seemingly asleep, for the shrimp vessels had already left and shimmering in the mirage on the horizon --forty-six within sight at one time—were busy hauling their shrimp trawls.

From the center, Barataria Bay is a huge expanse of water stretching to the horizon on all sides, but dotted here and there with low grassy marsh islands or headlands sometimes spotted with *cheniers* or clumps of low oak trees. Actually it is but 12 miles long and somewhat wider but very irregular in outline and



LIVE-OAKS

ALONG DUPRE CUT-OFF NEAR THE OLD RETREAT OF THE PIRATE LAFITTE NOW SHADE SUMMER HOMES.

very shallow. Like the other numerous bays of the Louisiana coast it has a soft mud bottom, thus providing an ideal environment for shrimp and small fish. The water is brackish, because of the heavy rainfall and outwash from the swamps and marshes, and because it is so shallow the temperature rises to 90 degrees or so during the summer. On the Gulf coast there are but two tides, one high and one low each twenty-four hours, but these have less effect upon water levels or water currents, except in the vicinity of the passes, than the winds which often bank up the water on the windward shores until it overflows the marshes Seaward, Barataria Bay is separated from the Gulf of Mexico by Grand Terre and Grand Isle, low-lying sand islands not unlike the barrier beaches of the Florida and Carolina coasts. In places trees with wind-clipped billowing tops shelter straggling communities of fishermen's houses, as at Grand Isle, and at the pass, Grande Terre rears a lofty eminence of forty feet or more, topped by historic old Fort Livingston, built in about 1814 and now, buffeted by southeast storms, crumbling and slipping brick by brick to a peaceful oblivion beneath the ninety-foot waters of the pass

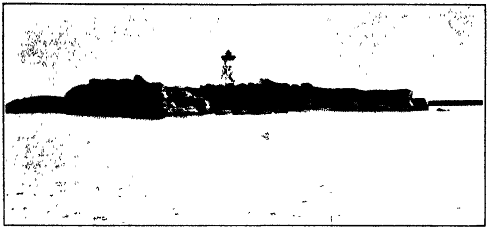
HYDROGRAPHIC OBSERVATIONS

IN THE GULF AND IN THE INLAND WATERS OF LOUISIANA WILL CONTRIBUTE TO AN UNDERSTANDING OF THE MIGRATIONS OF THE SHRIMP. HERE GOWANLOCH IS TAKING A WATER SAMPLE AND TEMPERATURE READING FROM THE BOTTOM.

THE SHRIMP TRAWL

IS BROUGHT ABOARD AFTER AN EXPERIMENTAL HAUL TO SAMPLE THE SHRIMP POPULATION IN BAYOU ST. DENIS.

Leaving the old fort and its stately landmark, Livingston light, the *Black Mallard*, feeling the long swell of the open gulf beneath her, heads south again to "twelve mile station," where periodic visits are made by the scientific staff for the purpose of collecting biological data on the shrimp and its habits. Reaching location where the lead showed 25 meters depth, the Greene-Bigelow water bottle with its reversing deep sea thermometers are put over at the forward davit and lowered to the bottom. After resting two minutes it is tripped by the sliding metal messenger, thus reversing the instruments, registering the water temperature and taking a sample of the bottom water, and then the whole



FORT LIVINGSTON

WITH THE PASSING OF PIRATES AND COLONIAL AMBITIONS OF FOREIGN GOVERNMENTS THE CENTURY-LONG VIGIL OF FORT LIVINGSTON GUARDING GRAND PASS HAS COME TO AN END.

apparatus is reeled in. Gowanloch squints at the delicate instruments and records the readings. Then the sample of water is drained from the instrument into a tagged glass bottle and set aside for salinity determination. A bit, however, is taken at once and placed in a color comparator to determine the pH, a measure of the acidity of the water.

While this is going on, the shrimp trawl is made ready and after the surface temperature and water sample is taken, the captain's whistle shrills "Stand by," as the vessel moves ahead. First the tail of the long bag-like net is put over the stern into the water, then the rest of the net goes overboard and Lindner and Gunter let go the otter

DOZENS OF VESSELS TRAWL FOR SHRIMP ON THE SMOOTH WATERS OF BARATARIA BAY.

boards and slowly pay out the towing lines. As the otter boards, hung like kites at the opposite sides of the net, catch the force of the water the net spreads out and settles to the bottom, the towing lines are made fast and the captain rings half speed ahead for the slow grind of an hour's hauling.

Immediately the plankton ring net is made ready and put overboard to tow at or near the surface from a special outrigger at one side of the boat. This net is a long conical bag one meter in diameter at the mouth made of silk mesh so fine that it will catch eggs or young of the shrimp or any other minute creatures more than 1/100 of an inch long. After towing for twenty minutes the plankton net is brought aboard and the catch is washed into a bottle and preserved for later study.

Soon the captain's whistle signals all hands to stand by for lifting the shrimp trawl. The gasoline winch slowly winds in the line, the boards are lifted aboard, the web of the net is hauled and if heavy it is swung aboard with a hoist from the boom. In this case the catch is light, however, and with only a moderate amount of heaving and puffing the boys land the catch by hand.

Spilled out upon the deck, our catch would have disappointed a shrimp fisherman. To the biologists, the catch provides a valuable record, for these men are prospectors seeking to find by persistent sampling just what kinds of sea creatures frequent this locality of the Gulf (and every other station visited) each week of the entire year. The shrimp of all sizes are quickly selected from the catch, whelks, crabs and other shellfish are noted and thrown overboard, and the fish are all sorted according to species, counted and recorded.

While the vessel proceeds toward the next station on its route the more exacting work proceeds. The shrimp are placed on the measuring table, where Gunter measures the length of each shrimp while Lindner records. In addition to the length, the sex and relative sexual maturity of each individual is noted, and a sharp watch is kept for those bearing the spermatophore, a structure involved in reproduction.

It is from the compilation and statistical analysis of the lengths of shrimp in hundreds of such catches and from catches of commercial fishermen as well that our biologists are able to deduce much of the life history of the species. Some hundred thousand measurements of shrimp from North Carolina to Texas have been thus analyzed. "Adding machine biology," some call it; others dignify it by the name of biostatics or biometry, and others lump it off as a part of fishery science. But science it is, for by such means is demonstrated

THE *BLACK MALLARD*

MAKES AN EXPERIMENTAL HAUL WITH STANDARD SIZE SHRIMP TRAWL IN BAYOU ST. DENIS.

that the two typical or "modal" sizes of shrimp present in any locality in the early summer are a year apart in age, that the smaller group just large enough to be caught by commercial gear are the young spawned during March, April, May and June, and that the larger group, the "Jumbo" shrimp, are the remaining few of the breeding class which, after spawning, disappear from the waters, never to be seen again,

doubtless dying after consummating life's destiny of reproducing their kind.

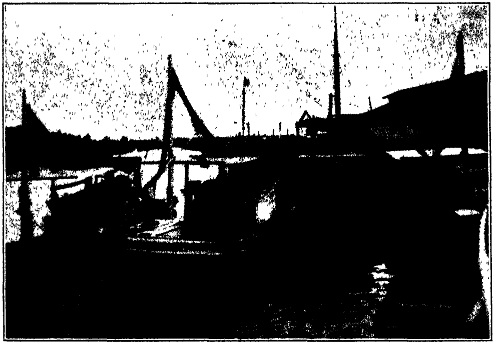
These length records demonstrate that growth is very rapid during the summer. Shrimp 2½ to 3½ inches long in July reach a size of 5½ to 6 inches by September. They also show that the breeding season is long, for females bearing spermatophores are found in the outside waters of the Gulf as early as April and as late as August and even September. The records show that young during all these months and on into the fall are growing up to commercial sizes and are joining the schools of more mature individuals spawned earlier in the year to carry on the mystic dance of swimming and feeding that makes the shrimp so elusive and baffling to the fishermen.

But what makes the shrimp so notoriously erratic in its appearance and movements? Sometimes they are more abundant in the bays, sometimes in the Gulf. One day good catches will be made, and on the next no shrimp can be found in that locality but will be taken in abundance miles away After cold storms larger shrimp may be caught, where formerly small or mixed sizes abounded. Does the shrimp react to changing temperatures, seeking water of a congenial warmth? Does it retreat before an inflow of saline water from the Gulf, seeking a more brackish environment?

Undoubtedly the species reacts according to definite laws, to variations in its environment; and to discover by actual observations what reactions take place in nature under certain conditions is one object of the research program of the associated governments now under way. From these repeated observations,

THE RESULTS OF A HAUL

THIS CATCH WOULD BE DISAPPOINTING TO A COMMERCIAL SHRIMP FISHERMAN, BUT IT HELD VALUABLE DATA REGARDING THE ABUNDANCE AND DISTRIBUTION OF SHRIMP FOR GOWANLOCH AND LINDNER.



VESSELS AT NEW ORLEANS WHARF

TONS OF SHRIMP ARE LANDED DAILY AT THE CANNERIES IN LOUISIANA. THESE VESSELS, WITH THEIR CATCH ICED IN THE HOLD, HAVE MADE THE RUN TO NEW ORLEANS FROM BARATARIA BAY.

hypotheses will be prepared, and later after experimental tests have been made disproving, modifying or confirming our theories, we hope to discover and state some of the natural laws governing the shrimp's life, that now appears to be guided only by caprice.

Returning landward from our most offshore station, hauls were made at regular intervals entering Barataria Bay, in mid bay, at the head of the bay, in Bayou St. Denis and so on, in thunder squall and under broiling sun throughout the day. Detouring through Bayou Rigolets we reach Little Lake, dragging our keel through the soft mud bottom to a favorable place for anchoring.

After breakfast the following morning a seining party, consisting of the engineer, the four scientists and myself, made ready to go ashore to search for young shrimp—shrimp too small to be taken by the commercial nets. The stern motor was swung overboard and fixed to the dinghy; the seine, lined with fine silk mesh, was put aboard with the collecting bottles and thermometers; and after invoking dark powers in a few well-chosen words the motor started for the half mile run to shore. As we left the *Black Mallard* anchored in three feet of water, the bottom gradually shoaled; two feet, one foot, six inches—finally the soft mud slowed us down, and we waded ashore onto a little sandy beach bordered by a wilderness of eight-foot marsh grass. The first foot that touched a bush aroused a hive of mosquitoes so hungry and fearless that half our time was spent in a losing battle with the pests.

Two of the boys quickly laid out the little collecting seine and hauled it

ashore, spreading out the glittering dancing catch on the webbing along the beach. Then all hands began the task of collecting a definite sample of the catch which, besides thousands of tiny fish, contained the wriggling shrimp.

When hatched, shrimp are very different in appearance from their parents. They are very minute, about 1/100 of an inch long, not unlike a water-flea in form. They soon develop an elongate shape with large head and eyes and a diminutive tail, whereas in the adult the head and thorax region is about equal in size to the large tail, which contains the muscular edible portion of the animal. As they grow, the larvae shed their skins, assuming a somewhat different form with each molt, passing through seven or eight distinct stages before attaining a form similar in external appearance to the adult although less than ½ inch long. At this size, however, the little shrimps are readily confused with other similar species that do not grow to large size and have no commercial value. It is this fact, doubtless, that leads fishermen to report a vast supply of young shrimp far offshore in deep water, for every coral head teems with a multitude of shrimp-like forms. The commercial species of shrimp, however, are seldom found ten miles from shore or in deep water; they are essentially coastal, brackish water forms feeding near the mouths of rivers on detritus from the outwash of the land.

Although it is fairly well established that the eggs of the shrimp, fertilized as they are laid, are cast free in the waters of the Gulf or ocean to develop and hatch, a mystery here develops that our investigators have not yet solved. The young post-larval stages, ½ inch or more in length, are found both near the sea and far up in the streams and lakes that are nearly fresh, containing one half to two parts of salt per thousand. For example, here on the shores of Little Lake, thirty miles or more from Grand Pass, our seines repeatedly take thousands of these fragile little creatures. What instinct guides them and what force propels them in making such a journey from salt to fresh water? We must assume that such a journey is

SEINING FOR LARVAL SHRIMP

ON THE SHORES OF LITTLE LAKE MANY MILES FROM THEIR ORIGIN IN THE GULF.

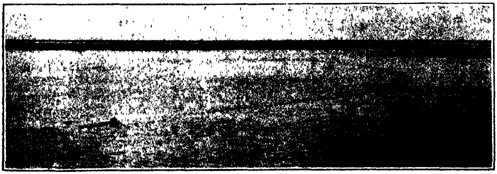
LAYING OUT A SEINE

A THREE QUARTER MILE LONG SEINE IS LAID OUT IN THE SHALLOW WATERS OF BARATARIA BAY NEAR MANILA VILLAGE. IN LOUISIANA THE SEINE IS STILL AN IMPORTANT METHOD OF CATCHING SHRIMP.

made and that it is the result of some unknown and possibly innate force, for there is no tidal flow sufficient to explain a simple drift against the normal outflow of land drainage. But nature is full of such mysteries, resulting, perhaps, from faulty observation of her ways or faulty interpretation of scanty data. Thus is the naturalist ever lured into the unknown.

Originally shrimp fishing was carried on with seines and cast nets, but the otter trawl has now generally replaced the older methods, except in Louisiana, where huge seines twelve hundred yards long still account for a considerable portion of the catch Following their introduction in 1916 or 1917 the otter trawl has become so popular that there were nearly 2,400 in operation in the southern states in 1929.

In addition to being sold fresh in local markets, shrimp are cooked and peeled for shipment and packed in iced cans for more distant markets as "fresh cooked." By far the greater amount, however, is canned either in tins or glass jars for domestic consumption in the



TWO SHRIMP SEINES IN OPERATION

THE OUTER ONE IS READILY DISTINGUISHABLE, MARKED BY THE CENTER FLOAT AND THE HEAD OF THE FISHERMAN STANDING NECK DEEP TREADING THE FOOT LINE. THE INNER SEINE MAY BE LOCATED ONLY BY THE CENTER FLOAT NEARER SHORE.

A BLACK-TIPPED SHARK

THE WASTE FISH THROWN OVERBOARD FROM THE SHRIMP HAULS ATTRACT MANY SHARKS, ESPECIALLY IN THE OUTSIDE WATERS OF THE GULF. IT TOOK BUT A MOMENT OR TWO TO CATCH THIS SMALL SPECIMEN OF THE BLACK-TIPPED SHARK, AND PROVIDED A LIVELY DIVERSION.

United States or dried for export to the Orient. During 1929 government records show that 767,852 standard cases of tinned shrimp were produced in the South worth $4,417,970. Of this amount nearly two thirds were of the wet pack, *i.e.*, packed in a salt brine, and one third was dry packed. More than fifty thousand cases of fancy large shrimp were packed in glass jars worth another half million dollars. These are the salad shrimp *par excellence*, and a tastier, more wholesome or nutritious bit of sea food is hard to find, unless it be in the better grades of shrimp packed in tins. Appearance of the product is the chief difference, but it accounts for a considerably higher retail price.

The canning process is a simple but highly effective one, repeating on a large scale the same type of preparation that would be practised in one's own kitchen. The shrimp are headed, washed, boiled in salt brine, cooled, peeled of the horny shell, graded according to size, placed in cans, sealed and sterilized. In one modern cannery in Louisiana I saw almost the entire process, except the heading and packing in cans, performed by machinery. No machine, however, can replace hand labor in removing the heads of the shrimp without robbing the industry of a bit of unique color In one large room, I saw four hundred laughing, singing, colored folk, boys and girls, young and old, working at long tables performing this process. They get ten cents a gallon for the headed shrimp and a skilful worker can make $3.50 to $4.00 a day. But who wants to work that hard? Since the job is piece work, one can have a better time earning less!

Before 1890, shrimp were dried in Louisiana by Chinese and Philippinos for export to their home countries, and the height of this early development is reflected in the name, Manila Village, where shrimp drying is still carried on. After cooking in brine the catch is spread out on huge wooden platforms to dry in the sun during the day and heaped under tarpaulins at night or in rainy weather. In the old days, the shells and heads were removed from the dried meats by treading with the feet. This "shrimp step" is a strange shuffling dance that has never become popular. Nowadays, the dried shrimp are tumbled in a perforated iron box and then screened to remove the shells. Nearly two and three quarter million pounds of dried shrimp were produced in the United States during 1930, yielding an income to the producer of $1,052,883.

The waste from canning is manufactured into a shrimp meal, used as stock feed, especially valuable for poultry because of its high mineral content, and into fertilizer. During 1930, 2,402 tons, valued at $69,345, were produced, but

this yield doubtless could be greatly increased.

All told, manufactured primary shrimp products and by-products netted producers $6,082,770. This is truly an important industry, and one worthy of development and perpetuation.

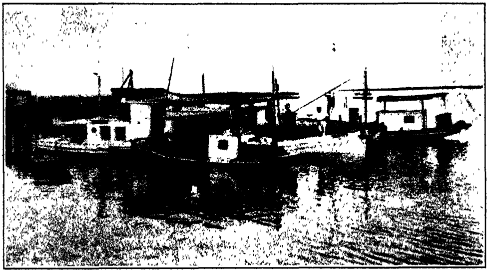
Carried on for half a century and locally appreciated, the shrimp fishery arose to the level of a great industry, providing an important food commodity following the introduction of the otter trawl. In recent years production has mounted by leaps and bounds, doubling itself about every eight and one half years until in 1931 a decline in landings began. Obviously such a rate of increase can not continue indefinitely, even though markets be available, for no animal can withstand such drain upon its numbers without impairment of the supply. Nature is bounteous but not boundless. It was feared that the limit of productiveness would soon be reached and that depletion of the natural supply would result in disaster to the industry, destroying the large investment of capital and depriving thousands of dependent workers of their livelihood.

As guardians of its natural resources, Louisiana took steps to forestall calamity by regulating the fishery industry and, in order to provide wise and effective laws allowing full utilization of the natural wealth at the same time insuring perpetuation of the supply, undertook a scientific study of the natural history of the important species. The U. S. Bureau of Fisheries had already undertaken an extensive study of the shrimp throughout its commercial range, and forces were joined with the state authorities in Georgia, Louisiana and Texas to make the work more effective. Dr. Frank W. Weymouth, a well-known scientist of Stanford University, who was already acquainted with the many species of shrimp on the Pacific Coast, was placed in charge of the bureau's research staff of six, including Dr. J. S. Gutsell in North Carolina, W. W. Anderson in Georgia, Milton J. Lindner and Gordon Gunter in Louisiana, and Kenneth H. Mosher in Texas. Louisiana's research staff, under Colonel H. B. Myers, include J. Nelson Gowanloch and Forrest Durand The Bureau of Fisheries assigned Launch 38 for work in Georgia and the motor vessel *Black Mallard,* which has been rebuilt and admirably fitted out by the state, was detailed for research in Louisiana waters.

The annual life cycle of the shrimp is a fact of utmost importance from the standpoint of conservation. In the late summer and fall, when the bulk of the season's catch is taken, the main body of the shrimp population is composed of

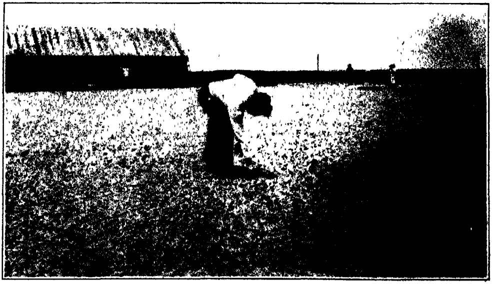
LARVAL SHRIMP

MIXED WITH SMALL FISH THE CATCH OF MINUTE LARVAL SHRIMP IN THE SILK-LINED SEINE WILL PROVIDE MANY HOURS OF WORK FOR WEYMOUTH AND LINDNER IN THEIR STUDY OF THE DEVELOPMENT AND EARLY LIFE HISTORY OF THE SPECIES.



LANDING SHRIMP AT A DRYING PLATFORM IN BAYOU RIGAULT

CRAFT OF ALL DEGREES OF SEAWORTHINESS ARE EMPLOYED IN THE SHRIMP FISHERY, BUT ALL ARE ALIKE IN THE CANVAS AWNING FOR PROTECTION AGAINST THE SUN.



ACRES OF SHRIMP ON A DRYING PLATFORM, BARATARIA BAY

AFTER BOILING IN SALT WATER, THEY ARE SPREAD OUT TO DRY. IN THE BACKGROUND THEY ARE BEING SHOVELED INTO BASKETS TO BE CARRIED TO THE HULLING SHED, WHERE THEY ARE TUMBLED IN A ROTATING METAL BOX PERFORATED WITH HOLES TO REMOVE THE SHELLS.

immature growing individuals that were hatched in the spring. None of them has yet spawned. Hence, if the fishery becomes so intense as to seriously reduce the stock at this time, there will be but few to survive the dangers of the winter to spawn in the spring. Certainly, the wholesale destruction of young shrimp early in the fall before they have grown to commercial size is a useless and inexcusable waste At this time the shrimp will double in weight in three weeks and a short delay in opening the fishing season in the bays where young abound would work but little hardship. "Jumbo" shrimp are most commonly taken in March, April, May and June Indeed, the young are just being spawned and there are no other sizes available. But the fishery, which reaches a secondary peak of production at this time, draws entirely upon the spawning population just prior to shedding the eggs. If this stock be too severely reduced there will be insufficient eggs laid to replenish the species and maintain the commercial supply. Since it appears that there is no second spawning it is imperative to save an adequate spawning reserve each year to secure the following year's crop

How this may best be done is still a matter of experiment. No method can *à priori* be prescribed with confidence; the effects of the present spring and summer closed seasons in Louisiana must carefully be observed through the medium of the detailed statistics now provided by law If changed regulations are desirable the biological facts now being laboriously amassed will be a reliable guide to effective and real conservation without which state, industry and public must continue to muddle through, depending on opinion, chance or whimsy.

THE PLANT COMMUNITIES OF THE DUNES

By Professor GEORGE D. FULLER
UNIVERSITY OF CHICAGO

MAN has always been interested in new things and in how these new things operate. The boy with a new watch wants to know what makes the hands go around, and he takes it apart to see how it is made and how it works. The student of nature is like the boy with the watch. He wants to know how the world came into being. He would like to have a new earth and watch it to see how the plants come in upon it, how the vegetation develops. Such an opportunity has been given on the shores of Lake Michigan, where for centuries new land has been continually in process of formation and new plant communities have been developing.

Many centuries ago a great ice sheet covered the northern portion of this continent to a depth of hundreds, perhaps thousands, of feet. The land was blotted out and all vegetation had disappeared. Some twenty thousand years ago this ice sheet melted and retreated northward from the United States. It left in its wake heaps of clay, piles of boulders, plains of sand, and pools of water. One of the largest of these pools has been named Lake Chicago, and after many changes has come to be the Lake Michigan of to-day.

The winds and the waves began their work on the shores of the lake as soon as the ice sheet had melted and the waters were clear of icebergs. The capes and headlands were first attacked by the force of the waves and were gradually washed away. The bays and inlets were slowly filled up. Some of the material removed by the waves soon sank to the bottom of the lake, but some of it traveled far and was then thrown upon the shore miles away Because of the west and northwest winds, currents developed in the waters of the lake and the south and east shores received tons upon tons of sand thrown upon the beach by the force of the waves and piled up into

FIG. 1. THE LAKE SHORE
WITH YOUNG DUNES BUILT UP AND HELD BY SAND CHERRIES AND WILLOWS.

sand-bars. When it dried the winds caught the sand from the beach, and carrying it away from the lake, piled it into small and large dunes. Century after century this went on until the new earth measured many square miles spread out as a crescent about the southern end of the lake.

The fascinating thing about this crescent is that while the outer edge is twenty thousand years old, the inner side was built up yesterday and is receiving further additions to-day. This permits the visitor to see new sand heaped up during the past few centuries or decades with its new communities of plants, the older dunes composed of sand maturing into soil with their older vegetation, and the oldest dunes with mature soil covered with the oldest vegetation, forming a climax forest upon climax soil.

When the sand first emerges from the waters of the lake it forms sloping beaches. The surface layers soon dry out and the sand is caught up by the wind and blown landward. It is uniform throughout and moves readily in the wind until it meets some obstacle like a bit of driftwood or a clump of grass. It then piles up into an embryonic dune that in turn acts as an obstruction to free sand movement and so the dune increases in size. During the day the surface of the sand is warm; in fact, in summer sunshine it becomes hot, the temperature rising at times to 120° or more. It cools rapidly at night until it is cooler than the air. These changes and the instability of the growing dunes create conditions which few plants can withstand in spite of the good water supply that is found a few inches below the surface.

Upon the beach a few scattered annuals grow during the favorable weeks of the summer. Upon the young dunes, however, a few seedlings manage to survive, and the first permanent plants are perennial grasses and shrubs. Among the most successful are the marram grass (*Ammophila arenaria*), the sand cherry (*Prunus pumila*) and two or three low willows. The marram grass has tough rootstocks with sharp pointed ends that make their way through the sand and are constantly invading new areas. These rootstocks are often ten to twenty feet long, and together they

FIG. 2. YOUNG DUNES ALONG THE SHORE

SUCCEEDED BY A PANNE WITH COTTONWOOD SEEDLINGS FOLLOWED BY COTTONWOOD DUNES IN THE RIGHT BACKGROUND.

FIG. 3. A PINE ASSOCIATION

DEVELOPED ON DUNES SHELTERED BY THE COTTONWOOD DUNES SEEN IN THE BACKGROUND.

form a network that tends to hold the sand in place. The sand cherries and willows are easily able to survive burial by sand as the dunes increase in size. One shrub thus becomes several, for each stem or twig covered sends out new roots and may soon become independent of the parent plant. Shoots, too, come up from the roots and assist in spreading the shrubs. This grass-cherry-willow association sparsely spread over the young growing dunes is the pioneer plant community (Fig. 1).

In depressions that are caused by wind sweeps between the young dunes or that have come from the filling up of lagoons surrounded by sand-bars, the sands are constantly damp, at least they are damp when the seeds of the cottonwood (*Populus deltoides*) are ripened in June These downy seeds are short-lived but easily carried by the wind, and when they fall upon the damp sand they germinate within twenty-four hours. Thousands of these seedlings may be found every summer in these "pannes," as the damp depressions in the dunes are called (Fig. 2). Most of these die during the scorching heat of July and August and others succumb to the gales and frosts of autumn and winter, but here and there a clump survives and lays the foundation of a cottonwood dune.

These clumps of young cottonwoods form a living obstacle to the moving sand, and growing dunes are formed These dunes are larger than those with grasses and shrubs, as trees grow taller. The cottonwood trees, however, are like the sand cherries and willows in sending out roots from trunks and stems that are buried and in sending up shoots from roots that are near the surface. Such spreading and multiplying trees, together with the willows and some of the grasses of the pioneer plant community, constitute the second plant community upon the young sands—the cottonwood

dune association (Figs. 2 and 3). This is an open community, the plants covering less than half the surface of the dune.

This openness and the greater size of the dunes results in instability and many of the cottonwood dunes are constantly moving away from the lake. As the new dunes appear the older ones get to be farther and farther from the lake. The younger dunes afford the older ones some shelter and more plants come in. These are the low junipers (*Juniperus communis*), the Jack pines (*Pinus banksiana*) with bunch grasses (*Andropogon scoparius*) and a carpet of bearberries (*Arctostaphylos uva-ursi*) with wintergreens (*Pyrola* and *Gaultheria*) twin flowers and many other northern plants (Fig. 3). The red cedar (*Juniperus virginiana*) and the white pine (*Pinus strobus*) soon join the community and a score of shrubs and herbs appear. They stand so closely together that they really form a forest and soon crowd out the earlier pioneer plants. The surface is well shaded, the sand can no longer move, and changes begin in it that are transforming the sand into soil.

As rain falls and snow melts the water passes down through the sand, removing certain minerals from the upper layers and carrying them down into the layers beneath. The pine needles and other leaves that fall to the ground lie there until they decay into humus that mingles with the upper layers of the sand. Dying roots also add their quota to the humus. The results are that the surface layers become darker in color, will hold more moisture and have a somewhat acid reaction. The water and

FIG. 4. AN OLDER DUNE

WHERE THE OAKS ARE INVADING THE PINES. A RAPIDLY ADVANCING DUNE IS SHOWN AT THE RIGHT.

FIG. 5. A BLACK OAK FOREST ON A LEVEL BIT OF DUNE SAND.

the vegetation are changing the sand into soil and making it ready for plants of a different sort.

In the shade of their parent trees pine seedlings do not thrive But scattered through the pine association are oak seedlings that grow the more vigorously because of the shade afforded by the pines. Hence in the competition which follows, the oaks gradually replace the pines (Fig 4), and on dunes a few thousand years old there is a forest of black oak (*Quercus velutina*) with a few scattered pines remaining and a few white oaks, sassafras and basswoods (*Tilia americana*) coming in (Fig. 5).

The oak forest requires more water than did the pines, hence the trees are not very large and they stand far enough apart to permit a great variety of shrubs and herbaceous plants to cover the forest floor. There are the dwarf and the aromatic sumach (*Rhus copallina* and *R. canadensis*), the maple-leaved viburnum and the bush honeysuckle (*Diervilla lonicera*), the choke cherry and the New Jersey tea (*Ceanothus americana*); while on the more sheltered slopes witch hazel (*Hamamelis virginiana*) and flowering dogwood are growing. Blueberries and huckleberries show that the soil is now acid.

There are few spring flowers in these oak dunes, but from late spring to the autumn frosts there is a succession of bloom that is unsurpassed. Before the end of May the sand violets (*Viola pedata*) are in bloom. They are followed by showy blue lupines (*Lupinus perennis*) and the delicately tinted hoary pea (*Tephrosia virginiana*), the pink wild roses (*Rosa blanda*), and the white phlox (*Phlox bifida*). Then come the yellows of the cactus (*Opuntia rafinesquii*), the frost weed (*Helianthemum canadense*), the puccoon (*Lithospermum gmelini*), the coreopsis (*Coreopsis lanceolata*), and the false foxglove (*Gerardia pedicularia*) passing into the orange of the butterfly weed (*Asclepias*

tuberosa). By midsummer the sunflowers, the black-eyed Susans (*Rudbeckia hirta*) and the wild bergamont (*Monarda punctata*) begin to bloom and are followed by blazing stars (*Liatris*), asters and goldenrods, while blue gentians and witch hazels are in flower when frost comes.

Soil changes now go on slowly, but more humus is gradually being incorporated into the surface sand and the humus from the oak leaves is less acid than that from the pine needles. The clovers and their relatives have also been increasing the nitrogen content of the soil, in a word, the soil is becoming gradually better and better.

The black oak association endures for centuries with little change, but gradually the better soil produces a better forest. White oaks and red oaks (*Quercus borealis*) gradually replace the black, and other trees such as basswood and maple (*Acer saccharum*) become more numerous. The trees are now larger, they grow more rapidly and form denser shade (Fig. 6). As a result, many of the summer blooming plants that were found in the black oak forest disappear from the red oak-white oak forest. The shade plants survive and the sun plants disappear. This forest community is really mesophytic.

Changes continue until on the oldest dunes, that are perhaps more than fifteen thousand years old, the richest of plant communities—the beech-maple-hemlock forest—becomes established. This forest is dense and the shade is deep; only trees that tolerate deep shade can grow in it. These trees are the sugar maple, the beech (*Fagus grandifolia*), and the hemlock (*Tsuga canadensis*), a few basswood and tulip trees

FIG. 6. RED AND WHITE OAKS

WITH AN UNDERGROWTH OF SUGAR MAPLE SEEDLINGS; A FOREST THAT IS ALMOST A CLIMAX.

FIG. 7 A CLIMAX FOREST OF MAPLE, BEECH AND HEMLOCK ON AN OLD DUNE

(*Liriodendron tulipifera*) and some remnants of the former forest such as an occasional red or white oak (Fig. 7). The other trees and shrubs of the oak forests have disappeared, having lost out in the competition with the beech and maple trees.

This forest is regarded as a climax, because it is the end member of a series of forests that have lived, died and decayed to make the climax possible. Then, too, it is the richest of all the forests in the region and it is able to reproduce itself indefinitely—it is a permanent climax

Within this forest shrubs are few, and they are quite different from those found with the black oaks. There is an occasional red-berried elder (*Sambucus racemosa*) or a bush of the tough-barked leatherwood (*Dirca palustris*), and some of the dune slopes are thickly carpeted with the ground hemlock or yew (*Taxus canadensis*).

The shade is so dense that most of the summer flowers have disappeared. The sand violets, the cacti, the lupines, the butterfly weed and the sunflowers have all gone Instead, there have come in a host of delicate spring flowers and a few shade plants that bloom in the early summer. Early in the spring flowers of the hepatica and bloodroot open and are soon followed by squirrel's corn, Dutchman's breeches and miterwort (*Mitella diphylla*); a little later there are long-spurred, white and yellow violets, golden bellworts (*Uvularia grandiflora*) and celandine poppies (*Stylophorum diphyllum*), white rue anemones (*Anemonella thalictroides*) and splendid masses of great white trilliums (*Trillium grandiflorum*). They are followed in the early summer by the white flowers of the sweet cicely and baneberry (*Actaea alba*), while there are columbines (*Aquilegia canadensis*) on slopes that get more sunlight. Ferns, too, have appeared.

There are marginal shield ferns (*Aspidium marginale*) and Christmas ferns (*Polystichum acrostichoides*) scattered throughout the woods, while the delicate maiden hair (*Adiantum pedatum*) and the golden spleenwort (*Asplenium acrostichoides*) are found in the more sheltered spots These are only the more common plants; others quite as beautiful may be found by the careful observer.

This richness and luxuriance in the plant community indicates a corresponding richness of soil quite different from the bare sand of the youngest dunes. Digging down there is seen a mature soil profile of three distinct horizons. First, underneath the dead leaves there are several inches almost black with the humus and leaf mould; then a thick layer of gray sand with particles of a mould and with some minerals leached from the soil above; while below comes the dune sand itself practically unchanged throughout the score of centuries that have passed since it was first cast up by the waters of the lake

Thus within this crescent of dunes forty miles long and five miles wide is condensed the history of twenty thousand years of plant development. Within the limits of a half day's walk one may read a summary of the succession of the plant communities that have developed throughout the period, a succession extending from pioneers on the new wave-washed, wind-blown beach sand through the shifting sands of moving dunes to older and older areas of fixed sand hills with better and better soil, producing succeeding generations of plant communities of ever-increasing richness, culminating in a permanent climax forest on climax soil twenty thousand years old There is no better place for the plant scientist to see how new land is formed and how it becomes mature soil with its succession of vegetation

SOMETHING ABOUT THE EARLY HISTORY OF THE MICROSCOPE

By GUSTAVE FASSIN

INSTRUCTOR IN MECHANICAL DESIGN OF OPTICAL INSTRUMENTS, UNIVERSITY OF ROCHESTER

On the milestones to civilization we find the names engraved of the men who have devoted their lives to the benefit of mankind. Let us dream back for a few minutes and pay tribute to the pioneers who laid the foundation stones for this temple of science which we are building.

THE specially-shaped transparent materials mentioned in some of our books dealing with the most primitive civilization are thought by modern writers to be lenses. For example, the elliptical quartz object which Layard found in the ruins of Nineveh was regarded by Sir David Brewster as a lens, and "Three Crystal Magnifying Lenses of Modern Form" (small discs with one convex side) found in the Minoan tombs at Knossos in Crete, are reported by the British School of Athens (session 1926–27) (Fig. 1).

In the classic literature of the ancients we find several chapters where lenses or mirrors are mentioned—Pliny tells us how Nero, being myopic, looked through a concave emerald to watch the gladiatorial combats. Seneca describes the magnifying power of glass globes filled with water. Burning-glasses, says Pliny, which were composed of glass balls filled with water were used by physicians to cauterize the flesh of patients. In "The Clouds," Aristophanes (B. C. 423) explained that the druggists of Athens sold transparent stones for kindling fire or melting wax by solar rays. Here, however, there is no clue to their shape or origin.

The first more or less scientific description of the magnifying power of shaped glass objects (plano convex in this case) is to be found in the book of the Arabian mathematician Al Hasan, who died in Cairo in 1038. One hun-

FIG. 1. AN ASSYRIAN "LENS"(?).

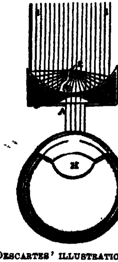


FIG. 2. DESCARTES' ILLUSTRATION OF A SIMPLE MICROSCOPE.

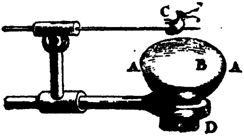


Fig. 3 Lieberkühn's microscope (1739).

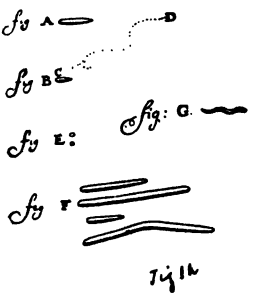


Fig. 5. Van Leeuwenhoek's "Little Beasts" as published in one of his books.

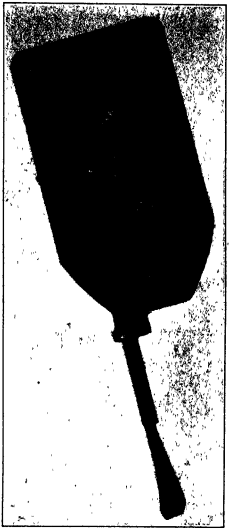
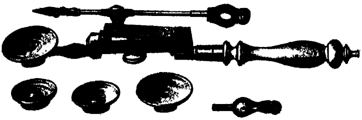


Fig. 4. Van Leeuwenhoek's microscope.



½ size.
Fig. 6. Compass microscope.

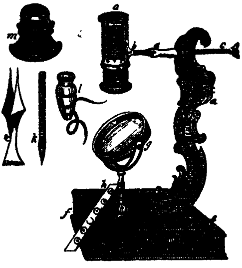


FIG. 9. WILSON'S MICROSCOPE WITH STAND.

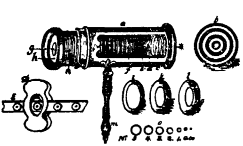


FIG. 7. CUFF OR WILSON'S POCKET MICROSCOPE.

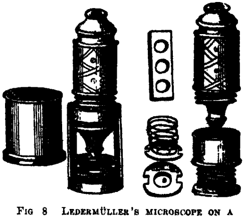


FIG 8 LEDERMÜLLER'S MICROSCOPE ON A SIMPLE STAND MADE BY BONAMI.

dred and fifty years later Roger Bacon (1214–1292) suggested the possibility of obtaining enlarged images by looking through spherical transparent materials of suitable densities.

Although glass was known from the earliest ages, the art of finishing it was very crude. In the thirteenth century the Venetians, in their enthusiasm for the manufacturing of a highly polished mirror, were using a slow grinding process, known at that time for polishing jewels.

Once the technique of polishing became known, the manufacturing of spherical surfaces did not cause much difficulty. The first application of polished lenses was made in correcting the eye. It is very difficult to decide upon the inventor of the spectacle lens; we hesitate between Signore Salvina Armato degli Armati, of Florence, and the priest, Alexandre de Spina, but the first appearance of the spectacle may be fixed, without error, at the last quarter of the thirteenth century.

The principles of the compound microscope were worked out by Johannes and Zacharias Janssens, of Middleburg, Holland, about 1590. In 1691 Mr. Bonani published a book giving a list of investigators engaged in microscopical research work. He mentioned, in the first place, Hufnagel, of Frankfurt, who in 1592 published a book about insects, with 50 illustrations. Soon after this a series of books about microscopical research work was published, and during the Thirty Years' War the simple microscope was generally known. We read in Descartes' "Dioptric et Meteora" the description of this instrument. He calls it "perspicula pulicaria ex uno vitro." This means "flie-glass with one lens." An illustration of this "flie-glass" occurs in his remarkable work. (See Fig. 2.)

A is a lens; this is not an ordinary

spherical lens but a convexo-hyperbolico-plano. The entire instrument is mounted in a frame C. The side of this frame, facing the light source, is a concave mirror which concentrates the light upon the small object fixed on the point of a prong E in the focus of the lens A

This particular instrument was made for hand use, but Descartes proposed a microscope of larger size based on the same principle. Here, however, we observe the use of a condenser lens, instead of a parabolic mirror to concentrate the light on the object.

The instrument shown in Fig 3 was specially used for the microscopical study of insects The optical toy called the "flie-glass" was well known. When the famous priest Scheiner died, a "flie-glass" was found in his possession. His neighbors regarded the "flie," seen through the glass, as the devil and looked upon Scheiner as a magician

The most famous of the microscopists at that time was Antonie Van Leeuwenhoek, who was born in Delft on October 24, 1632, and died there on August 26, 1723. He made his microscopical studies a hobby, polished his own lenses and made all the mechanical parts of his microscopes himself. Through the documents of his time and also through his published works we learn that his lenses were excellent and that he was a master in making microscopical preparations. In 1674 he gave the first accurate description of the red blood corpuscles and investigated the structure of the teeth, the crystalline lens of the eye and other physiological objects. In 1680 he stated that yeast consisted of minute globular particles. Fig. 4 represents a microscope as used and made by this scientist.

A small lens is fixed between two metal plates. On the one side is a specimen holder, which can be moved up and down by means of a screw. A screw for focusing was also provided. The illumination of the object was arranged, as in the Descartes' instrument. A concave mirror was fixed around the lens, but generally he worked only by transparencies. The magnification of this instrument was in some cases as high as 160X.

Van Leeuwenhoek was also the first microscopist who gave a description of bacteria. Fig 5, taken from one of his

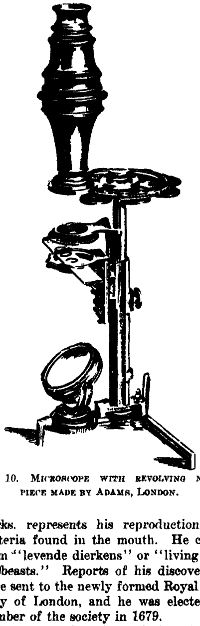


FIG. 10. MICROSCOPE WITH REVOLVING NOSE PIECE MADE BY ADAMS, LONDON.

works, represents his reproduction of bacteria found in the mouth. He calls them "levende dierkens" or "living little beasts." Reports of his discoveries were sent to the newly formed Royal Society of London, and he was elected a member of the society in 1679.

For a long time the optical perform-

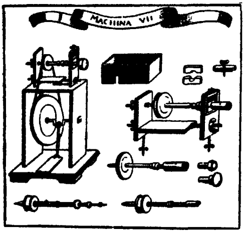


FIG. 11. OPTICAL MACHINERY AS USED IN THE EIGHTEENTH CENTURY.

ance of Van Leeuwenhoek's microscope was not improved nor even equaled, but the mechanical construction developed rapidly. Van Leeuwenhoek is a brilliant example of what a man, animated with the love of science, can produce. He was an amateur, not a professional microscopist. It is remarkable to see how he worked, basing his theory on his observations instead of on his philosophical reasoning, such as had been the usual custom before this time.

Professor T. Musschenbroek improved the mechanical part of the microscope, by making it possible to change the objective lens in the microscope for different magnifications. Van Leeuwenhoek had used a different instrument for each power. Musschenbroek built his microscope on a base so that the operator had the use of both hands. He also used the knee-joint stand for the first time to provide a comfortable observing position for the instrument.

About the same period we find the compass-microscope (Fig. 6). One leg of the compass carries the lens; the other, the object. The distance between the two elements could be adjusted by means of a screw. A Descartes' mirror was used for illumination. This, too, was a hand instrument.

A real improvement was made in the construction of the instrument by Ledermüller, who calls it a Cuff's or Wilson's pocket microscope (Figs. 7 and 8). Between an object holder A, the specimen is pressed against a diaphragm by means of a coil spring The lens is mounted in a tube which screws in the body tube of the instrument and provides in this way an accurate focusing device. This instrument was further provided with a condenser lens and interchangeable diaphragms made out of colored parchment or thin sheets of metal.

Fig. 9 shows real progress in the mechanical construction of this instrument —the microscope is built with a stand. A mirror for illumination is provided. m,k,l,i are the different tools used by this instrument. From 1704 to 1750 a great number of instruments of this type were made with slight improvements.

The photograph, Fig. 10, is one of the first microscopes, made by Adams, of London, which was provided with a revolving nose piece with 8 lenses.

Johannes Zahn published in his "Oculus artificialis" Fig. 11, which repre-

FIG. 12. HOOKE'S COMPOUND MICROSCOPE.

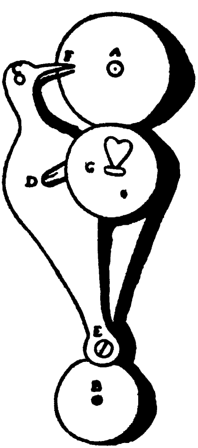


FIG. 13. GRAY'S WATER DROP MICROSCOPE.

sents the machinery which was used at that time to grind and polish the lenses. The polishing of the very small lenses used in microscope objectives was a very difficult problem, and they tried in another way to obtain a usable product—namely, by melting the glass into very small balls, which on some occasions gave very good results; Professor Harting tells us that with such a lens Hartsoeker studied spermatozoa, and this work certainly needed a very high magnification. In a Dutch review "Prometheus," 1895, Professor Brunk gives a complete description of the manufacture and use of such glass ball microscopes.

The inventor of this method, Robert Hooke, published in 1665 his "Micrographia" (written in English) which contains 60 microscopical observations, made and described with the greatest accuracy. We find also a complete description of a "compound microscope" (Fig. 12). The tube length was 6 or 7 inches, but could be very much lengthened by means of several draw tubes. An object lens and two eye lenses were used; one of these lenses was a field lens and "could be eliminated to reduce the refraction, by observation of small objects." A glass ball filled with water was used as condenser.

This microscope was manufactured in 1667. Hooke, although a man with a disagreeable disposition, was a most remarkable experimentalist. His observations were made with the greatest precision and his microscopical drawings were full of details. In the description of his work he says, "Then examining it according to my usual manner by varying the degrees of light and altering its position to each kind of light. . . ."

The monk Giovani Maria dela Torre

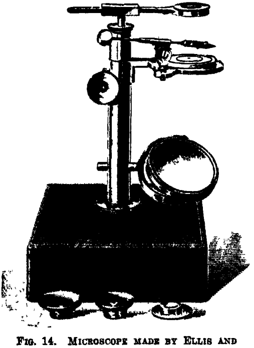


FIG. 14. MICROSCOPE MADE BY ELLIS AND VAN CUFF.

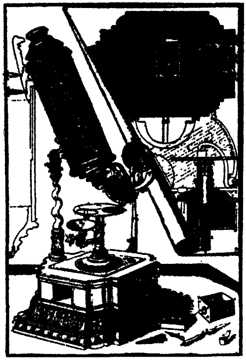


FIG. 15. MICROSCOPE MADE BY PROFESSOR HERTEL.

was famous in the manufacturing of small microscopic lenses, made by the smelting method, invented by Hooke.

A very curious instrument was made by Gray, who used a very small drop of water as objective lens. Fig. 13 represents the Gray's microscope. The opening A held the small drop of water that served as objective lens; the object was fixed on the beak F or in the opening C when infusoria were to be examined.

Griendl Van Ach was famous for his good microscopes. He assembled plano-convex lenses following a method given by the Italian Divini. The convex sides of the lenses were turned toward each other, and the whole objective was a combination of three such pairs.

About 1750 Ellis and Van Cuff manufactured a microscope with a construction comparable with the more modern microscopes. With this instrument (Fig. 14) he made a remarkable study of corals. The use of a condenser lens was well known in his time, but he was the first to build this lens into a mechanical device, so that focusing was possible. Charles Darwin, 100 years later, used a similar instrument in his research work.

A micro-focusing device or slow motion screw was suggested by Pritchard and first applied in a type of microscope made by the English manufacturer Ross

The German Professor Hertel (1703) combined in his microscope all the perfections of the eighteenth century. In this instrument, however, the focusing device was incorporated in the stage, together with a device, similar to the modern mechanical stages, for moving the stage from left to right and back and forth. (Figs. 15, 16 and 17).

In England Marshall, Cuff, Baker and Jones now became well known for their instruments—especially Marshall, who manufactured powerful objectives and made them interchangeable.

The greatest step forward in the op-

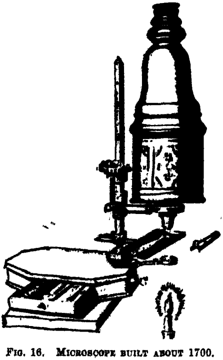


FIG. 16. MICROSCOPE BUILT ABOUT 1700.

tics of the microscope was made through the manufacture of achromatic lenses. The first achromatic objective for telescopes was made by John Dollond (1706–1761), following the suggestion of Leonard Euler, the mathematician. Some scientists claim that credit for this is due to Chester More Hall (1722).

The first achromatic objective for the microscope was presented by the Russian state counsel Aepinus in 1784 to the Academy of Science of St. Petersburg. This instrument had an objective of 7 inches focus, and, therefore, a very low magnification. Its length of 3 feet made it very difficult to handle.

The first useful and good achromatic objective was made by the Dutch cavalry officer, Frans Beeldsnyder, in 1791. It was composed of two convex lenses of crown glass with a bi-convex lens of flint glass between them. The focal length of this lens was 21 mm and it had wonderful definition.

The first achromatic microscopes were constructed by Van Deyl and son, and Fraunhofer in München, but the magnifications were low and the competition with the simple microscope difficult. Selligue's idea of using a series of several achromatic systems was worked out by the brothers Chevalier. With the realization of this high power achromatic objective the simple microscope was superseded.

The same brothers Chevalier were the first to cement the lenses together with Canada balsam. Amici, French mathematician, improved in 1815 the objectives by turning the lenses with their plano side toward the object, so reducing the spherical aberrations of the Chevalier system in which the convex side was toward the object. Amici was also the first to use one complete objective for each magnification instead of screwing the lenses together to make more or less powerful combinations.

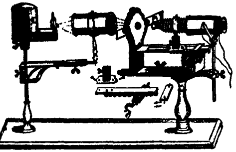


FIG 17. MICROSCOPE WITH ILLUMINATION EQUIPMENT CONSTRUCTED IN 1691 BY BONANI.

The immersion system and the correcting of the objective for the thickness of the cover-glass were Amici's inventions.

Ross and Wenham made their objectives adjustable for different thickness of cover-glass—a technique which is still in use

In Europe, with Zeiss, Abbe and Schott, the microscope reached its highest perfection. In the United States, Spencer and Bausch and Lomb were the pioneers in the field of microscope manufacturing, and their daily contributions toward science and industry are of inestimable value

This brief history of the early microscopes brings us up to the closing quarter of the nineteenth century. Even then there was much left to be done. In 1870 there were only 50 microscopes in this country. In 1930 there were at least 50,000 in use.

This great development was influenced partly by the steady growth of scientific activities, but great credit must also be given to the early microscopical societies, with their large memberships of amateur microscopists. These amateurs did for the microscope what the radio amateur did for the advancement of radio. Now that science has made the instrument its own, there are few amateurs left, but microscopy still remains one of the most fascinating of pursuits.

OPTICS AND MODERN PAINTING

By Dr. ROGERS D. RUSK
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THERE is perhaps no field of thought in which pseudo-scientific explanations have been more confused or more in actual error than in the optics of modern art. At the same time these declarations have been made with an air of finality and authority that could scarcely be more misleading, and they have masqueraded under an apparent profundity which at least to the layman was incontrovertible. The reason may be that the problem of the artist when stripped of its intellectual and emotional attributes is purely an optical one and yet the artist is not often a scientific expert in optics, but rather he is one who would forget science in his search for what is "not-science." In no art, however, except music is the technical basis of the art more exacting or more clearly defined than it is in painting, and as little as the artist may care to admit it, or as little as he may care to consciously cater to it, optics in one form or another is a chief essence of his object and method.

Primitive man attacked the problems of rendering form in two dimensions on the walls of his cave, and in three dimensions on his totem poles and images, but it was not till the time of Piero della Francesca in the fifteenth century that the first real conquest was made of the problem of representing three dimensions on a two-dimensional surface. One by one the various optical problems involved in painting have been thus attacked—chiaroscuro, perspective, shadows, design, and finally the problem of color, about which the Impressionist group was so greatly concerned and with regard to which there is yet so much misstatement and mistaken thought.

In the latter part of the nineteenth century the little group of Impressionists fostered by Manet and Monet introduced a new era in the use of color and light which in due time became the most important influence in modern painting. In this same century came that remarkable development of the modern theory of light in which the supremacy of the Newtonian emission theory was overthrown by Young and his followers, and the wave theory was accepted. Furthermore, the scientific principles of color relation were being formulated by Chevreul, Helmholtz, Maxwell and others, and these new discoveries opened up wide horizons and presented a statement of basic principles hitherto unrecognized. Such new levels of thought and action, whether technical or esthetic, are noteworthy for the way in which we suddenly come upon them, although the preparation may have been quietly going on for generations, and it is not surprising that a new era in art should accompany this technical revolution in so closely related a field.

There is even a deeper philosophical basis for the change in view-point. The Kantian philosophy had swayed Europe and had called attention to the difference which must exist between things-as-we-see-them and things-in-themselves. The positivist had gone much further and said that we must only talk in terms of sense-impressions. Ruskin and even Chevreul had applied the term "impression" in art, and Manet in 1867 had staunchly asserted the right of a painter to render his own personal impression. When, along with others, Monet used this term in the title of his picture

"Impression, soleil levant" in the exhibition of 1874 it became fixed upon the group as a name to signify the new movement, in spite of Monet's own objection to being tagged by it. It is not the name Impressionism with its many connotations which is important but rather the movement toward a full knowledge and a bold use of the newly discovered color relations, for which also the not altogether satisfying terms luminism, chromatism, divisionism and even "chromoluminaristes" have been suggested After all it is perhaps best not to try and displace a term so generally accepted and which carries with it an emphasis on more than the merely technical phase of the movement.

Without the name, and without even the group, the revolution in painting would have come sooner or later under some name and with some group because the way had been paved by the necessary advance in optics. Whether or not we have passed beyond the immediate circle of influence of Impressionism or Post-impressionism is likewise unimportant, for no matter which way the pendulum swings to-day the influence of the new optics of light and color is unmistakable and lasting. It furnishes a powerful technique for the artist to use as consciously as he pleases. It reveals to us the world of color in which we live, and furthermore it parallels the interest of the scientific world in the light which furnishes our world with life and color and which purveys to us most of our knowledge of the universe from stars to atoms.

No artistic movement in modern times ever suffered more resistance nor were its adherents held up to more public calumny and actual shame than those who were officially barred from the Salon of 1863, who first exhibited as a group in 1874, and who received little or no encouragement till the eighties. However, the movement toward a liberation of our ideas of color and light, both technical and esthetic, is as real to-day as when it was first conceived and now, nearly sixty years since the group received its name, it is more than time that the commoner misconceptions of the optics of the movement be cast aside.

It has been said that Monet was "a great eye" (even Cezanne was heard to murmur it), but that is scarcely an adequate optical explanation of his art, for likewise he was a great hand and, because by his own admission he only painted his pictures as far as his vision would allow him, his hand was as great or greater than his eye. No doubt the central nervous system should also receive its share of credit—as even a behaviorist would have to admit. A leading biographer[1] of Monet enthusiastically declares that he possessed a spectroscopic eye, which led him to paint pictures that were "perfect demonstrations of the theory of atomic dissociation." This statement can be taken as hardly more than pseudo-science at its worst. Unfortunately for the figure of the great eye, which is pleasant enough in itself, the ability of an artist can not be localized in one member and indeed every real artist must have a "great eye."

A statement as definitely at odds with common optical principles as that of the "spectroscopic eye" is the statement attributed to Sargent, who thought the colors were produced on Monet's retina by his astigmatism. However, the most prominent effect of astigmatism is the well-known blur of lines in one direction with sharp focus of lines at right angles, and headaches rather than color effects are the prevailing results of such trouble, as plenty of astigmatics will testify. Color effects, if they did exist, would probably provide surprising colored borders to objects, and in no way the effects

[1] Camille Mauclair, "Claude Monet," p. 29.

reported on canvas by Monet. It is true that Monet suffered from eye weakness, and long exposure to bright sunlight may very well have hastened his failing sight, but the Impressionist movement can hardly be attributed to this, and rather it must be thought that Monet achieved his results in spite of weakness of vision

A more obvious effect of astigmatism is the lengthening or shortening of an image, and this has been often invoked to explain the elongated images of El Greco. Indeed by holding a correcting astigmat lens before an El Greco figure it shrinks to very much its natural proportion. Unfortunately for this theory, however, El Greco's earlier pictures were in normal proportion, and the distortions suddenly came to him on his visit to Toledo from Italy Now it is a well-known fact that astigmatism is a very slowly progressing defect, if it progresses at all, and by no means does it attack one with such furious suddenness Furthermore, and most unfortunate of all for the theory, El Greco painted at least one picture, "The Burial of the Count of Orgaz," in which appear both distorted and undistorted pictures at the same time. We are left to fall back on the not unsatisfying conclusion that El Greco knew very well all the time the effects he desired and the means he proposed to use to gain those effects.

It is in the subject of color theory, however, where the most egregious blunders are committed, and these are the more to be regretted because of the many who have pretended to write on the subject of color under the cloak of more or less technical authority. There may be some excuse for certain lesser blunders in the fact that even to-day artists and scientists in optics may haggle over the use of terms in spite of committees that have been appointed to iron out their differences. There is no excuse, however, for such an error, a common one it must regretfully be admitted, as occurs in a standard book on modern French painting[2] It is stated in illustration of the blending of closely juxtaposed spectral hues that a more brilliant green is to be obtained not by mixing pigments representing the adjacent hues of yellow and blue, but by the light from the closely juxtaposed pigments mixing or blending in the eye Unfortunately, yellow and blue are the only two colors in the spectrum which when blended in the eye will not produce the color located between them, but quite on the contrary in the proper proportion they will give a white considerably reduced in brightness

This goes back to the whole misconception of color of Sir David Brewster and others, which Sir David had expounded not wisely but too well about the middle of the century and which was called severely into question by Helmholtz in 1852 Indeed, it was this very fact, that green is the one color which can not be produced by blending other colors in the eye, which had led Young at the very beginning of the century to assign green as one of the three primary sensations of the retina. This assignment later disputes have failed to displace, but it had to be rediscovered by Helmholtz in Young's earlier papers. Then once and for all became crystallized the famous distinction between the "red, green, and violet" primaries necessary to explain the additive effects of colors blending on the retina, and the "red, yellow, and blue" primaries, which had long been used to explain the subtractive effects of mixing pigments. The difference between mixing pigments and mixing colored lights in the eye was a long time being straightened out, but straightened out it has now been for

[2] Jan Gordon, "Modern French Painters," p. 22, 1923.

many a day and there is not the slightest excuse for such errors being perpetuated either by art critics or by pseudo-scientists. Indeed from the notes of Leonardo himself it appears that even he had recognized the uniqueness of the green

But what of the other colors which may legitimately blend to produce that color located in the spectrum between them? A second fallacy now appears because of the simple fact that there is not anywhere near complete blending of the colors in the eye as there may be in nature itself unless the spots are absurdly small or the distance of the observer absurdly large A simple experiment will show this, and it is usually a surprise to the experimenter to observe how far away quite small spots of juxtaposed color of different hues can still be observed as separate spots One can appreciate this by backing away from a picture done even as delicately and minutely as Seurat's "La Grande Jatte." It was to get around this difficulty that the later exponents of so-called pointillism experimented with smaller and smaller spots, only to find that as the spots became smaller and smaller the time necessary to apply them became longer and longer, and the mosaic produced was less painting in the ordinary sense and more and more a craft.

From the view-point of optics a good way to aid the juxtaposed colors in blending together would be to produce a slight rapid motion of the object so that the retinal images continually overlap or are successively superposed as may be easily shown by experiment. To pursue this suggestion to its unhappy logical conclusion, it might seem best to hang Impressionist pictures from a kind of electric vibrator. However, one can scarcely imagine the justifiable amazement and indignation of the esthete on entering a gallery and beholding favorite copies of revered masters executing an indescribable jiggling tango upon the walls of the museum, while more staid and classic ancestors looked on from other walls in calm rebuke. Very obviously it is not so much the blending of the colors as their relative contrast which is essential Some critics rather picturesquely call it the *collision* of the colors, others call it the vibration of the colors, which is rather unfortunate, as the actual vibration of a light wave is something entirely different and amounts to hundreds of trillions per second, being of course wholly unperceived by the eye. It is this contrast or collision which reproduces the dazzling brightness or the softer shimmer of sunlight. When the critics speak of the greater brilliance so obtained the term must not be interpreted as measuring brightness, in the physical sense, because the eye may not receive appreciably more light from the area covered by two closely juxtaposed hues than if the mixed pigment were spread uniformly over both areas That is a matter which involves the question of reflection coefficients and the chemical and physical effects of mixing pigments. If the term brilliance be so used as to imply contrast effects and not mere brightness the fact must be recognized Some word indeed is needed to convey this idea, which is a chief element in the optics of Impressionism.

We see then that Impressionism brought with it an enlarged recognition and use of the principles of color contrast, and the distinction between the problems of the additive color combinations on the retina and the subtractive color combinations of mixed pigments. The major credit for formulating the first statement of the principles of color contrast must be awarded to Chevreul, the chemist, in spite of the fact that he labored under some of the current misconceptions. Chevreul turned his atten-

tion to colors in the interest of the Gobelin tapestries and published his significant treatise on the laws of simultaneous color contrast in 1839. The problem presented to Chevreul was simply why does black cloth sometimes seem black, sometimes seem a rusty brown or sometimes a deep blue? Surely a chemist of such fame should be able to tell if the dyes are at fault, and if the customers who have complained have the right to financial redress. To answer such a question the chemist proved his ability by turning physicist, and in the end enunciating laws more fundamentally psychological than anything else. The problem, however, was not new. The artist of to-day speaks of a color as "telling" differently on the picture than alone on the palette, and in the early days of painting with limited colors this fact was fundamentally important. A gray in the eyes often would "tell" as a blue. Such deception through contrast was well known, but its laws were not known until the work of Chevreul by whom they were first set down in logical form

Chevreul also saw that the so-called local color of an object might be one thing, but its appearance under different illuminants was something else. The surface atoms of a substance not only may not tell us of the underlying reality, but they tell a different story under different kinds of illumination To-day we know that when a surface appears blue it may actually be reflecting quite a range of wave-lengths, and blue may simply be the predominating effect which has been registered by the eye. It is the old story of the difference between the Kantian phenomena and noumena, and through it we are led to the positivistic view that for us as observers the sense impressions are the important things. Chevreul showed that these sense impressions are relative, and so as Einstein put relativity into the world of space and time, so also did Chevreul put relativity into the world of color.

The first step in the rediscovery of reality through the medium of color and light was the return of the naïve recognition that green leaves might be painted green, and later came the climactic discovery both in optics and by the artists themselves that green leaves might be painted orange, blue, violet or any other color, depending on a variety of controlling factors. Later in the century Rood was to publish in his book a chart showing that green leaves actually reflect, in addition to some white light, not only green but also strong yellow and red. These ordinarily blend on the retina to give a yellowish green, but when such leaves are viewed in the light of an intense blue sky they may reflect a much bluer green, or in the light of the setting sun more nearly a red or orange.

Delacroix was the first of the moderns to rediscover the world of color—see, for example, his Massacre of Scio done in 1824—and his biographers assert that his interest was so great when the theories of Chevreul were later published that he studiously constructed charts of his own and made an attempt to see Chevreul in person, which was only frustrated by illness. The world of art owes much to Delacroix, but it was Manet years later who was always recognized as the leader of the group that met so regularly on those Friday evenings at the Café Guerbois and who put the new movement on its feet. According to Duret it was Manet who gave Monet the inspiration which led to the movement as we now know it. Manet's genius had led him to a use of clearer and purer color and to that elevation of the key of the palette necessary to represent appearances in sunlight. That same genius led him to a recognition of the elusive

character of local color and to the recognition that shadows may not be mere absences of light but simply regions of lesser illumination, where colors interplay on a lower key. It was inevitable that along with increased color-sense the key of the palette should be raised more and more—likewise inevitable, perhaps, that to-day the key of the palette should have sinking tendencies—a natural reaction, the true measure of which we can not yet take.

In the middle of the nineteenth century discussions on the nature of light filled the air (perhaps one should say the ether). Maxwell was about to bring out his famous electro-magnetic theory. Photography had arrived and was being eagerly accepted. Rousseau, to a certain extent Corot, and others of the Barbizon school had gone into the fields and painted effects as they saw them, not as they imagined their ultimate realities to be. Small wonder is it that sunlight and appearance came to mean something in themselves, and small wonder is it that these things should point the way for discerning minds toward a new trend in color. The original scientific labors of Chevreul, Helmholtz, Maxwell and others were ably seconded in spreading the new knowledge in palatable form, especially as it referred to art and painting, by several more popular writers and commentators, chiefly Rood in America and Von Bezold in Germany. These texts, which were published shortly after the Impressionists became consolidated as a group, were translated into several languages and one can not doubt their ultimate direct effect in causing the acceptance of the movement and at least their indirect effect upon the leaders themselves. Strange as it may seem, there is serious question as to whether Monet and some of his contemporaries ever looked into any of these books. They were concerned with painting, not in studying optics, and their ideas of the new trends of color theory were perhaps obtained second-hand over their glasses of wine in studio or café, perhaps through their acquaintance with the enthusiastic Charles Henry. Seurat certainly studied the texts with avidity in constructing his scientific formulas and also Signac, who gave us a record of the movement in his book "From Delacroix to Neo-Impressionism" and who even made a pilgrimage in 1884 to discuss matters with Chevreul in person.

However it was that theory and practise got so closely together in these two great movements, the scientific and the esthetic, it is true that in the origins of the Impressionist movement their fundamental proposals harked back more to Newton and his prism than to Chevreul and Helmholtz. Newton had shown that sunlight on being passed through a prism is spread out into a rainbow band, and he indicated the seven colors of the spectrum, now more often reduced to six. In this rainbow band, as every one knows, these six colors seem to stand out, and hence we speak of the six spectral colors: red, orange, yellow, green, blue and violet. Optically there is a continuous sequence of wave-lengths from the longest to the shortest, and something like a thousand different hues can even be detected by the eye. The selection of six is hence a purely psychological matter. At any rate the idea grew that under the blessing of Newton's experiment with the prism, appearances in sunlight should be represented by the so-called six spectral hues (plus white) in various spottings and juxtapositions. White was to be used to raise the key of the palette toward that of sunlight, and black was to be banned from the shadows where lower lights and complementary colors were to creep in. Thus was the formula set forth for him who could to follow.

The colors in shadows had been observed by Leonardo and later by New-

ton, and the idea of their complementary and partially subjective nature gradually grew through the labors of Brewster, Fechner, Plateau and others. As for the principle of juxtaposition its origin is less distinct. It has been a favorite game of speakers and writers on the subject to trace juxtaposition back to this or that painter—Delacroix, Constable, Turner or Watteau. But it is difficult to tell how much of the germ of the idea was there. While one is in the mood for such a game it is not difficult to further trace the germ back to Leonardo and even to Aristotle. There were among the ancients some very keen observers and often they set forth with inadequate logic what has had to be rediscovered many times since.

One after another of these ideas of contrast, divisionism, spectral hues and high keys was pushed to its limit by those whom we now know as Impressionists and their followers, and so did Impressionism and its attendant "isms" wax and wane. So also did these painters in one experiment after another establish and reestablish the new optics in their own domain, partly through conscious effort to do so, partly through conscious attempt at realizing certain new esthetic aims, and partly through a dim unconscious striving. To a movement which has had, and will continue to have, so much influence on modern art we certainly owe a better and more complete understanding of its optical basis.

THE OCCURRENCE OF OIL AND NATURAL GAS

By Dr. FREDERIC H. LAHEE
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In a great many ways we are all directly or indirectly interested in petroleum. Natural gas, widely used for heating and cooking in many parts of the United States, is one variety of petroleum. Crude oil is another; and from crude oil are made such products as gasoline, naphtha, candle wax, lubricating oil, and so on.

From a different angle, many of us possess securities in the form of bonds or stocks in companies organized to drill for petroleum or to refine and market it. Because of these diverse interests which we have in petroleum, we ought to know more about it, how it occurs in its natural state underground, and how it is discovered and brought to the surface.

The name "petroleum" is applied to a group of solids, liquids and gases, all composed of hydrogen and carbon in various proportions. Among the solid forms are asphaltite and ozokerite. Crude oil includes the liquid forms. Natural gas will be used in this article for the gaseous forms, although actually there are other natural gases, such as helium and carbon dioxide.

Crude oil and natural gas are found in minute openings in rocks. These openings are usually the pores between the grains of a sand or sandstone or small open spaces in limestone. That there is considerable space between the grains of a sand may be demonstrated by filling a jar of known capacity with sifted sand of uniform grain. After the jar is full, as much as 30 per cent. of its capacity in oil or water may be poured in to fill the voids between the grains. In its rock form of sandstone, the total pore space is not commonly as high as 30 per cent., for the grains vary in size and the small ones partly fill the spaces between the larger ones. Furthermore, there is usually some mineral substance which has been deposited between the grains, thus helping to bind them together to make the solid rock. In most oil-bearing rocks the pore space amounts to at least 15 per cent. of the rock volume.

In the past history of the earth, broad sheets of sand, mud and limy material, many square miles in extent, were laid down one upon another on the broad shallower parts of the sea floor, in fact much as they are being laid down today; and during the long period since their deposition, these older sheets have been gradually buried, compressed, sometimes hardened into rock, and more or less warped and broken. Thus, we now find that in some regions these rock strata—now called sandstone, shale or mudstone, and limestone—show signs of having been bent in broad wrinkles or folds, which are called anticlines if the fold is arched upward, and synclines if the fold is trough-shaped. The wrinkles in a blanket or in a piece of paper which has dried unevenly after wetting may be compared with the great arches and troughs in rock strata (Fig. 1).

When rock layers have been broken, the masses on the two sides of the fracture have often slipped, one block moving downward with respect to the other. These fractures are called faults, and the rocks which have been broken and have slipped against one another are said to have been faulted (Fig. 1).

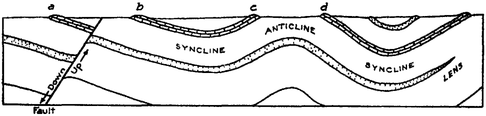

FIG. 1. VERTICAL CROSS SECTION TO SHOW THREE PRINCIPAL TYPES OF GEOLOGIC STRUCTURE WITH WHICH OIL AND GAS MAY BE ASSOCIATED. THESE THREE TYPES ARE THE "ANTICLINE," THE "FAULT" AND THE "LENS." *a, b, c* AND *d* ARE OUTCROPS OF THE SAME ROCK FORMATION WHERE IT APPEARS ON THE SURFACE OF THE GROUND (SEE FIG. 2).

Rock layers are not all of uniform thickness. Indeed, they are much more likely to vary, and they may thin to such a degree that they wedge out altogether, as illustrated in the "lens" in Fig. 1.

Any of these forms in which rock strata are found in nature are called geologic structures. There are many kinds of geologic structures, but anticlines, faults and lenses, with their numerous modifications, are the principal varieties in which we are now interested from the standpoint of petroleum.

It is commonly true that water, usually salt water, is contained in the pores of sandstones and other pervious rocks, at depths of a few score of feet, to several thousand feet below the earth's surface. Quite possibly these porous layers have been filled with water since they were first laid down, but if so the original water has probably been replaced or modified by underground circulation and chemical action.

Where oil and water are associated together, either in an open vessel or in the pores or openings of a body of rock, the oil takes a position above the water, because it is lighter than water. It floats on the water. Also, if gas and oil are contained in a closed vessel, or in a porous rock capped by an impervious layer which prevents escape of the fluids, the gas, being the lighter of the two, will rest upon the oil.

Porous rock strata, such as sandstone and limestone, if overlain by impervious layers, may contain oil and gas where they have been bent in anticlines, or where they have been faulted, or where they wedge out in a direction up the slope (called the "dip") of the beds. These three cases are shown in Fig. 2, where XY is a porous sandstone layer. Note that in each case, true to their specific gravity relationships, gas (finely stippled) is found in the upper part of the structure, oil (solid black) is next below the gas, and water (coarsely stippled) lies below the oil. If only oil and water are present in the pores of the rock, then the oil occupies the upper part of the structure.

To describe the geologic structure in which oil and gas may occur is easy, but to discover such structures is difficult. In the earlier days of geologic exploration for oil, between 1905 and 1920, search was made, on the surface of the ground, for outcropping layers of rock which could be mapped and which, by their distribution and dip (tilt or inclination), indicated the nature of the geological conditions underground (Fig. 1). Thus, the more conspicuous structures were located. But later, as the search for more structures continued, the surface evidences were found to be more and more obscure, and consequently more and more refinement and care were needed in geological work. Recourse was had to diamond drilling to secure core samples of the rocks; to airplane

mapping; and to the application of several kinds of highly technical methods for examining the magnetic, electrical and other physical properties of rocks below the ground surface.

The point to be emphasized here is that the search for new geological structures favorable to oil or gas accumulation becomes increasingly difficult as time goes on. Moreover, no one can tell from the surface whether porous strata are present on the structure, and no one can tell whether such strata, if they are present, will be found to contain oil or gas. The best that any one can do is to map what he thinks may be favorable structures and, basing his judgment on the results of drilling in the surrounding areas, draw some rough conclusions as to the possibilities for porous strata and for oil or gas in these strata. Nothing but the drill will tell the true story. It is well worth remembering, therefore, that any person who, in advance of actual discovery of oil, asserts that he "knows" that oil is present at any particular locality, or beneath any designated spot, is making an unreliable claim; and any written statement which purports to be a geological report is unreliable if, in the same manner, its author professes to have definite knowledge of the presence of oil where oil has not yet been actually seen or produced.

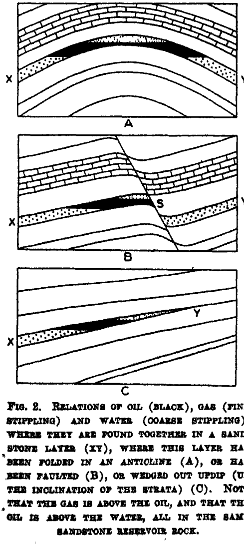

FIG. 2. RELATIONS OF OIL (BLACK), GAS (FINE STIPPLING) AND WATER (COARSE STIPPLING), WHERE THEY ARE FOUND TOGETHER IN A SANDSTONE LAYER (XY), WHERE THIS LAYER HAS BEEN FOLDED IN AN ANTICLINE (A), OR HAS BEEN FAULTED (B), OR WEDGED OUT UPDIP (UP THE INCLINATION OF THE STRATA) (C). NOTE THAT THE GAS IS ABOVE THE OIL, AND THAT THE OIL IS ABOVE THE WATER, ALL IN THE SAME SANDSTONE RESERVOIR ROCK.

Where the oil and gas came from and how they collected where they are now found are two problems not yet settled by scientists. We feel certain that most petroleum is a product from the decomposition of organisms, probably both animals and plants, but we do not yet know the exact processes of this decomposition; and we are fairly certain that the oil and gas in many localities where they now occur have gathered there by moving through rock pores or other rock channels from the surrounding region, yet we do not know just how they have moved. For the present the facts concerning the origin and migration of petroleum remain in obscurity.

Formerly, before the true nature of oil occurrence was understood, the prevailing idea was that it was practically unlimited in supply and that it moved from place to place more or less as underground rivers. What ideas were held were for the most part rather hazy. But now, with a vast store of information derived from tens of thousands of wells, we know that both oil and gas, even though they are in the small pores of rocks, occur as isolated, definitely bounded accumulations, often referred

to as "pools" or "fields." We also know that within each such pool the oil and gas are under pressure, due partly to the weight of the overlying rocks and partly to hydrostatic pressure from the water flanking the oil within the porous reservoir rock. And finally we know that the gas, while under sufficient pressure, serves as a most valuable agent in moving oil through the pores of its containing rock to the lower end of the well, and then in lifting this oil through the well to the surface. In this way the gas, as natural energy within the reservoir, is of very great importance in facilitating the extraction of oil from below ground.

Any method of development—and by "development" we mean drilling the wells and producing the oil—which dissipates the reservoir energy, by wasting the gas, or taking the gas out of the pool unequally, or taking it out too rapidly, reduces the efficiency of the energy available in the reservoir and thus reduces the quantity of oil which will eventually be recovered. Wide experience in many regions has shown that evenly spaced wells throughout the area of the pool are more conducive to maintenance of reservoir pressure than uneven spacing where the wells are crowded together in some places and wide apart in others; and experience has also shown that the decline in reservoir pressure which is generally observed in producing fields can be retarded and kept more uniform by regulating the flow of oil in all the wells instead of allowing them to produce wide open. A gusher, pouring out hundreds or thousands of barrels per day, is a thrilling sight, particularly for the owner, but as long as it flows unbridled and without consideration of its relation to other wells in the field, it is trespassing on the prospects and the rights of other owners in the pool, both owners of leases and owners of royalty alike.

Unless a pool is drilled and operated systematically and efficiently, with full regard for the proper utilization of the reservoir energy, not only are the individual rights of the owners jeopardized, but—more important—oil in large quantities is left underground where it can never be recovered. No matter how carefully the wells are drilled and operated, there is always a certain percentage of the oil which can not be extracted, and which is therefore left in the pores of the reservoir rock; but by poor practises in drilling and operating, a much larger proportion of the oil originally present in the pool may be permanently left in the ground.

Petroleum is one of our greatest national resources. It is a diminishing asset which we can not afford to waste. It should be wisely produced and wisely utilized. Not only for the sake of property-owners in the pool, but also as a national obligation, every oil and gas pool merits the application of orderly and scientific methods of development.

SCIENCE SERVICE RADIO TALKS

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MEASURING A MILLIONTH OF A SECOND

By Dr. J. W. BEAMS

PROFESSOR OF PHYSICS, UNIVERSITY OF VIRGINIA

ONE of the surprises encountered by the student in science is his first realization of the amazing speed with which some of the elementary processes in nature occur. Accustomed as he is to observing things through his senses, it naturally imposes a considerable tax upon his imagination to visualize the rapidity with which these elementary phenomena are taking place round about him. For example, the average human eye can not distinguish between two light flashes that occur in less than about one sixteenth of a second of each other. In fact, it is this property of the eye that makes possible the smooth continuous moving pictures, or causes the familiar electric light or neon sign to seem continuous without flicker, even though their light usually consists of a series of flashes. On the other hand, experiments have shown that the actual time required for the light itself to stimulate the retina, or, in other words, to be absorbed by the eye, must be millions of times less than one sixteenth of a second.

The ordinary stop-watch with which we are accustomed to making our precise measurements of the time, between our every-day events, is seldom graduated in divisions of less than one tenth of a second because of the inability of the average individual to operate it in shorter times than this. However, when we compare this one tenth of a second, or the shortest time we could possibly measure with our ordinary stop-watches, with the time required for atomic or molecular interaction to take place we find that the former is very large indeed. For example, in the air that surrounds us the average time between two collisions of a molecule is about one five-billionth of a second, and the average time required for this same molecule to give off light after it is stimulated by means of, say, lightning or an electric spark, is around a hundred millionth of a second. In other words, these events take place in about the time it takes a fast rifle bullet to penetrate one one-hundredth of the thickness of a page of writing paper.

It therefore long ago became apparent to the physicist that if complete studies of many natural phenomena were to be made it would be necessary to devise direct methods of distinguishing between two events happening within a fraction of a millionth of a second. In other words, instruments must be constructed capable of recording events faster than they occur in the phenomena under investigation. Fortunately for this purpose nature has endowed us with some phenomena that take place much more rapidly than others, so that those occurring in shorter times may be utilized to study those of longer duration, or the faster moving things may be used to measure the slower ones.

At this time I can outline only one or two of the numerous methods used by the physicist for observing things that happen in these extremely short times, or to indicate briefly even a minute portion of the vast amount of valuable in-

formation both from the scientific and practical standpoint obtained by their use. An experiment any one can try is to look at the reflection of a light in a hand mirror and to rock the mirror rapidly. If the light is steady, like that of a candle, the reflection is strung out into a streak. On the other hand, if the light is not steady, like that of the familiar red neon sign, a row of separate images appear as the sign is lighted and extinguished. This results from the fact that as the mirror is turned the successive flashes of light from the sign enter the eye from different directions and hence fall at different places upon the retina.

If, instead of looking at the reflected light from the turning mirror, it is allowed to enter a camera, each flash falls in a different position on the photographic plate so that the photograph shows a row of pictures of the separate flashes. If then we know how fast the mirror is being turned we can find the time between the flashes. The faster the mirror is turned obviously the greater the distances between the images on the retina or the pictures on the photographic plate. This device of the rotating mirror is one of the simplest and most useful at our disposal, provided the mirror be spun with very great speed.

To do this we mount the mirror, which is usually made of stellite, on a cone-shaped piece of metal called a rotor, that looks something like a schoolboy's spinning top. This rotor fits into a similar hollow metallic cone containing openings from which jets of air at high pressure are blowing. However, the rotor is not blown out of the cone but floats on the air like a ball on a fountain jet, while small grooves on it conspire with the air jets to set it spinning. Rotors of this kind have been spun up to a half million revolutions per minute. To study an electric spark, for instance, the light of the spark is thrown into a camera by the spinning mirror or we may watch it in the mirror by the eye. We can make the image of the spark move so fast that two views of it one one-hundred millionth of a second apart appear as separate. With the aid of this rotating mirror it is found that the electric spark starts as a narrow thread and expands radially; also that the different colors of its light, called spectrum lines or bands by the physicist, do not all appear simultaneously but come off at different times, the light from the air atoms and molecules appearing before that from those of the metallic electrodes.

Light, together with the family of phenomena to which it belongs called electromagnetic radiation, travels with a velocity in excess of 180,000 miles per second. These are the fastest moving forms of energy known to man. Yet, the rotating mirror just described turns through a measurable angle while light travels less than ten feet. As a matter of fact, the velocity of light can now easily be demonstrated and roughly determined, utilizing a light path within the confines of an ordinary room.

We could spin these mirrors faster if our materials were strong enough, but at higher speeds the rotor would be torn apart by the very great centrifugal force developed. Incidentally, these rotors have found application as a centrifuge for separating heavy liquids from light ones, as in the case of the cream separator. So great is the centrifugal force that the outward pull on the material is more than a million times its weight. Under such conditions, for example, cream should rise from milk in a very small fraction of a second.

Fast as the rotating mirror is, there are devices which work still more quickly. You are probably familiar with the fact that the vibrations of light are crosswise, like waves in a stretched cord, not forward and backward like sound waves. Ordinary light is a mix-

ture of vibrations in all directions, at right angles to its line of propagation, but certain crystals can single out one of these directions. If a stretched horizontal rope is confined between two vertical guides you can send an up-and-down wave along it but not a crosswise one. Our crystal devices, called Nicol prisms after their inventor, put the light waves, so to speak, between guides. If we send a beam of light upon two such prisms crossed at right angles no light will come through, although each prism by itself seems transparent.

If we put certain transparent liquids, such as water or carbon disulfide, in the light path between these two crossed Nicol prisms nothing is changed, but if an electric field is properly applied to the liquid, light will come through. This phenomenon is called the Kerr effect, after its discoverer, and the arrangement in which the electric field is applied to the liquid is called a Kerr cell. Effectively, then, this arrangement of a Kerr cell between the two Nicol prisms is a light shutter, because it allows light to pass when the electric field is applied and extinguishes or stops the light when the electric field is removed from the Kerr cell. The time required for this Kerr effect to take place or to vanish after the electric field is applied or removed in a liquid is very short; for example, in carbon disulfide it is probably less than a billionth of a second.

It is this property of the Kerr cell light shutter of responding almost instantaneously to electrical control that makes it, in its variously modified forms, of great value in studying short-time phenomena as well as in immediate practical applications. It has been used in many researches, including studies of the electric spark and other discharges; studies of the time element in fluorescence; studies of the time required for light to eject electrons from a photosensitive metal, or in other words the time required for the photoelectric effect to take place; and even for measuring the velocity of light. Among its practical uses is its application to television.

Time does not permit a discussion of the many other beautiful methods, such as the electric or Lichtenberg figures, cathode ray oscillograph, or Wilson cloud chamber, any of which can record events that happen in times much shorter than a millionth of a second. However, in closing, it may be of interest again briefly to call your attention to the difficulty of conceiving of such short times as a millionth of a second. For example, an automobile running a mile a minute would move about a thousandth of an inch in this time, while a fast airplane could travel less than one tenth of an inch. Yet difficult as it is to imagine, we now have at our command several different methods of recording events that happen in considerably less than a hundred-millionth of a second; or, in other words, we now have methods of measuring a millionth of a second with as much precision as we can measure a minute with the best stop-watch or ten minutes with an ordinary watch.

SLEEP

By Dr. S. W. RANSON

PROFESSOR OF NEUROLOGY AND DIRECTOR OF THE INSTITUTE OF NEUROLOGY, NORTHWESTERN UNIVERSITY

Why do you spend about eight hours a day or one third of your time in sleep when there are so many interesting things to do for which you can find no time? The obvious answer that unless one gets adequate rest one soon becomes

exhausted and life not worth living justifies this use of time, but it does not explain how and why sleep comes. What makes consciousness disappear, the muscles relax, the heart rate decrease and the whole organism, body as well as brain, begin to repair the damage sustained during the preceding day and to lay up new stores of energy for the morrow? Think about this some wakeful night when you lie with muscles tense and thoughts whirling in uncontrollable eddies through the long hours that the much-needed rest escapes you. I doubt if you will find the answer, for the problem still puzzles the scientists who have given most thought to its solution.

Many theories have been advanced, but they are all unsatisfactory. I shall mention only two of them. It has been supposed that during activity fatigue substances are produced and accumulate in the blood and that these have a narcotic action on the brain. The accumulation of these substances would thus periodically induce sleep, during which they would be excreted from the body, thus allowing for the return of the waking state. But against this theory are the facts that sleep, as in an afternoon nap, may come when there is little fatigue, that extreme nervous fatigue often leads to insomnia, and that normal sleep, unlike ether narcosis, is easily interrupted by noise or other disturbances.

Yet it is a matter of common observation that sleep ordinarily comes easily to one who is physically fatigued. A soldier after a long march finds it difficult to remain awake on the eve of battle. In laboratory tests it has been found that after two or three days of continuous wakefulness the tendency to sleep is almost irresistible and if the subject of the experiment is allowed to sit quietly in a chair he will drop off at once. Yet if kept awake by frequent prodding he is mentally alert and capable of solving problems in a normal manner. It is certain that under normal conditions sleep comes long before a state of exhaustion is reached that greatly impairs efficiency. The change from the waking to the sleeping state is abrupt and can not be explained by the gradual accumulation of waste products of activity.

Another theory, which at one time received considerable attention, is that during sleep the conduction pathways in the nervous system are broken by the retraction of small contact points between the neurones which are the conducting units of which the nervous system is composed. If this occurred it would stop nervous activity just as effectively as pulling all the plugs from a switchboard would stop all communication over that telephone system. But there is no evidence that such retraction occurs.

The habit of sleeping at night is acquired early in life. It is the first habit which a mother tries to have her baby acquire. Many animals, like new-born infants, have several periods of alternating wakefulness and sleep in twenty-four hours. White rats have ten such periods of rest, totaling, on the average, fourteen hours out of every twenty-four, the greater part in the daytime. The ringed snake is a good sleeper. It awakes at noon, is active for one and a half hours and then retires and is perfectly quiet until the following noon.

In man the habit of nocturnal sleep seems to be definitely related to the importance of visual sensations. Rats which depend chiefly on the sense of smell can afford to take naps in the daytime and make up for lost time by foraging at night.

Dogs are active in the daytime and sleep at night, partly because their activity is guided largely by information gained through their eyes and partly because their habits are adjusted to correspond with those of men. But Kleitman has shown that if the superficial layer of gray matter, which is known as

the cerebral cortex, is removed from a dog's brain the animal loses the habit of nocturnal sleep and has five or six periods of sleep alternating with activity each twenty-four hours. When awake these dogs are restless and walk around and around in the cage

These observations are significant for our problem. They show that the habit of sleeping at night is dependent on the cerebral cortex. It is not surprising that the removal of the cortex should disturb the rhythm of the sleeping and waking states, for it is this layer of gray matter on the surface of the cerebral hemisphere which is the part of the brain that is responsible for what we call consciousness. One might, therefore, not have been greatly surprised if these dogs, deprived of their cerebral cortex, had slept all the time. But since they had frequently recurring periods of wakefulness and activity it is clear that sleep must involve something more than the inhibition of cortical activity Other parts of the brain must also be quiescent in sleep.

The cortex is the covering of the cerebral hemispheres which form the greater part of the forebrain; behind this there is the midbrain and still behind that is the hindbrain. It has recently become known that there is a small region in the midbrain near its junction with the forebrain that has a very important relation to sleep

This is the region involved in a form of sleeping sickness known to physicians as encephalitis lethargica. Although there are records of epidemics in the past which may have been manifestation of the same disease, it first became known to modern medicine as an epidemic which broke out in Europe during the world war. This epidemic started in Vienna in 1916, and became wide-spread in Europe the following year. In 1918 the disease appeared in England, and in March, 1919, the first cases were reported in the United States. Since then cases have appeared sporadically in almost every country; and this summer there has been a fresh outbreak of the malady in St. Louis.

With the onset of the illness the patient becomes drowsy and if left to himself sleeps day and night. Yet he is not comatose, but can be easily aroused much as from normal sleep. There is usually some paralysis of the muscles which move the eyes, indicating that the portion of the brain from which the oculomotor nerve arises has been damaged Post-mortem examination of such cases has shown wide-spread inflammation of the brain, but the most severe damage is at the junction of the midbrain and forebrain just in front of the origin of the oculomotor nerve, which supplies the eye muscles Because of the frequency with which drowsiness and pathologically prolonged sleep are associated with paralysis of the eye muscles in this disease, and the location of the chief lesions and most severe damage just in front of the origin of the oculomotor nerves it has been assumed that this region at the junction of the forebrain and midbrain has some special significance for the regulation of sleep.

Von Economo, a Vienna neurologist, was the first to draw this conclusion from a study of cases of encephalitis lethargica He spoke of this region as a sleep center; but by this he did not mean to imply anything more than that it was in some way concerned with the regulation of the periodic alternation of the waking and sleeping state. This supposition is strengthened by the fact that cases are on record where this same region has been destroyed by hemorrhage or abscess or has been pressed on by tumors and these patients have slept continuously for weeks at a time Neurologists now recognize pathologically prolonged sleep as a symptom pointing to a damage of this part of the brain.

Recently we have been able to produce

a similar condition experimentally in cats by destroying a small sharply localized area in this part of the brain. While this was being done the animals were under deep anesthesia so that neither at the time of the operation nor afterward did they suffer pain. In making these lesions we have used an apparatus which makes it possible to place the tip of a needle-like electrode at any desired point in the brain. Through this electrode, which is insulated, except at the end, there is passed a very weak electric current that slowly destroys the brain substance for a short distance around the end of the needle, thus making a small spherical lesion

When by this method we have placed small lesions on each side of the midline in the region corresponding to von Economo's sleep center, the cats have slept almost continuously for days or weeks following the operation. They can, without much difficulty, be wakened and made to walk about the room or jump from a table. But they are disinclined to move about, take no interest in their food nor in a mouse placed before them. As soon as they are left alone they drop off to sleep again. In many ways they present a striking resemblance to patients with encephalitis lethargica.

We have not been able to produce this condition of prolonged sleep by similar lesions in other parts of the brain, and it now seems certain that this particular region has special significance for the regulation of sleep. Why a lesion so placed should upset the normal rhythm of activity and make the animal sleep almost continuously we do not know any more than we know why patients with similarly placed lesions are so drowsy. But these animals furnish a means of attack on some of the problems presented by sleeping sickness and excellent material for studying the nature and cause of sleep.

TULAREMIA

By Dr. EDWARD FRANCIS

MEDICAL DIRECTOR, UNITED STATES PUBLIC HEALTH SERVICE, WASHINGTON, D. C.

I ASSUME that by this time you all know what tularemia or rabbit fever is—almost everybody in the United States does. If not, then you had better ask some housewife to tell you about it before you shoot your next rabbit. It is one of our most popular diseases in the fall of the year when everybody wants to shoot a rabbit. About one thousand persons contracted tularemia, or rabbit fever, in the United States during the past year from skinning or dressing wild rabbits.

Well, what is tularemia anyway? It is a disease of wild rabbits which causes their livers and spleens to become spotted all over with a million small spots and causes the death of the rabbit. In addition, the germs grow and multiply in every part of the rabbit's body, including the blood and muscles. Ordinarily only about one in every hundred of the wild rabbits is infected, but, sometimes, the disease becomes epidemic among them and then we see dead rabbits lying everywhere.

The liver of an infected rabbit is recognized by the spotted appearance of its surface. A million small round spots become plainly visible on the liver of an infected rabbit on the third or fourth day of its illness, but these spots are too tiny to be seen on the first and second days of illness; therefore, if a rabbit is shot on the first or second day of illness the liver, although diseased, will appear healthy.

Hunters who shoot and dress rabbits

become infected in dressing them. Their bare hands become covered with blood when they pull out the livers and spleens. If by chance there is an open cut or sore on the hands, the infection travels from the rabbit's blood or liver into the wound on the man's hand and gives him tularemia or rabbit fever When a rabbit is shot the bones often become shattered into small fragments by the shot; if, in dressing a rabbit, one of these sharp fragments pierces the skin of a man's hands the infection enters at that place. Sometimes the infection penetrates the normal skin of the hands in the absence of an evident wound.

Then, in about two or three days illness begins with a headache, chilliness, vomiting, aching pains all over the body and fever. The patient thinks he has the "flu" and goes to bed. The sore on the hand develops into an ulcer. The glands at the elbow or in the armpit become enlarged, tender and painful, and later may develop into an abscess. There is sweating, loss of weight and debility. Illness lasts about three weeks and is followed by a slow convalescence covering a period of two or three months. Most cases recover without any bad after effects, but about five cases in every hundred die, especially if complicated by pneumonia.

One who has recovered from an attack of tularemia need not fear a second attack, because then he is immune against the disease. Market men who skin and dress rabbits year after year contract the disease only once. Therefore, if there is some job requiring the handling of wild rabbits give the job to an immune—to some one who has had the disease once.

Prevention is the keynote of modern medicine. Keep your bare hands out of a wild rabbit. Rubber gloves afford sure protection to hunters, market men, cooks, housewives and others who must dress wild rabbits, but remember that sharp fragments of shattered bones can easily pierce a rubber glove and puncture the hand. The liberal use of soap and water and disinfection of the hands are recommended to remove blood from the hands or even when the hands have only come in contact with the rabbit's fur.

Thorough cooking of all wild game, especially rabbits, is essential Thorough cooking will render infected rabbit meat entirely harmless for food, because the germs are easily killed by the heat of thorough cooking. But, if any red juice is allowed to remain about the bones the germs will remain alive and virulent in that red juice. Eating of insufficiently cooked wild rabbit meat has caused three serious outbreaks in each of three families who ate the meat Three members of one family died. Three died in another family and two died in the third group.

A warning to the poor sportsman is necessary. He should not shoot the rabbit which is on the end of his gun—that one is probably a sick one. Let him shoot his rabbits on the run; shoot only the lively ones. Avoid the rabbit which has been found dead, and the one which the cat or dog has brought in, and the one which a boy has killed with a club—they are all probably sick. The women of the country are coming to the rescue. They are telling their sportsman husbands to bring home the birds but to let the rabbits lie as they fall—do not bring home the rabbits.

In all that I have said you will notice that domesticated rabbits have not been mentioned. The disease has never been found in rabbits raised under domestic conditions, as in rabbitries and hutches, and sold for food and sold for pets. These rabbits, however, are just as susceptible to experimental infection in the laboratory as are the wild rabbits.

A fisherman in Texas found a dead jack-rabbit, which he cut up into some small pieces, putting one piece on each

of his fish hooks for bait. He caught no fish, but three days later he went to the hospital with tularemia. A farmer in Minnesota cut up a rabbit which he had found dead on his farm and fed it to some silver foxes which he was raising in a pen—expecting that some day he would sell the silver fox furs for some lady to wear around her neck. But, fifteen days later, the farmer was dead from tularemia. A farmer in Montana was sick. He called his doctor, who drove 75 miles to see him. The diagnosis was a mystery until the farmer, pointing out of his window and up the slope of a hillside, called the doctor's attention to many white spots on the hillside and added that each white spot was a dead snowshoe rabbit That farmer was the first case of tularemia in Montana. Making a diagnosis of tularemia is like working a crossword puzzle; the trick is to find the letters which spell "rabbit."

A golf champion of national reputation was wintering in Florida and was playing a golf match when suddenly he realized that his golf game was slipping away from him. Spying a dead rabbit lying on the golf course and being a bit superstitious he quickly pulled out his knife, cut off the rabbit's left hind foot and secretly slipped it into his pocket, expecting a change of luck. But, in the excitement of the quick amputation, a sharp fragment of rabbit bone punctured the golfer's finger That was enough, because two days later the golfer went to the hospital for a month's illness with tularemia. *Moral:* Know your rabbit, brother!

Up to this point I have spoken only of wild rabbits, but there are ten other kinds of American wild life that have given tularemia to people. I will name them: Wood-ticks, horse-flies, tree squirrels, quail, sage-hens, opossums, ground-hogs, muskrats, skunks and coyotes.

Wood-ticks of Montana and the surrounding states become infected by biting wild rabbits. They then convey the infection to man by biting him beneath his clothing. Dog-ticks in ten of our southern states not only bite dogs, but they bite rabbits and then the ticks convey the infection to people whom they bite Ticks are notorious for their ability to transmit disease because of their habit of imbibing at every bar they come to, and when the list of their drinking places includes both rabbit and man then the man goes to the hospital. Blood-sucking flies in Utah and the surrounding states bite horses and cows, but they also bite rabbits and man, thus conveying the infection from rabbits to man

Quail live on the ground and they associate with rabbits and become infected by ticks, which first bite the rabbits and then bite the quail. During the hunting season man shoots the quail, and in dressing them he becomes infected through his hands just as he does when he dresses a rabbit Sage-hens, like quail, live on the ground in close relation to rabbits, and therefore they exchange ticks with the rabbits This may cause the sage-hens to become infected, and then they transmit the infection to the people in Montana who dress them.

The red squirrel, the gray squirrel and the black squirrel have caused tularemia in people who dressed them Opossums, in some sections of the country, are skinned and dressed for food. If they happen to be infected with tularemia they pass the infection on to the person who dresses them, just as an infected rabbit does. Ground-hogs and rabbits may come together in the same holes in the ground. If infection should travel from the rabbit to the ground-hog then the boy who skins the ground-hog for its fur becomes infected through his hands. Muskrats are skinned for their fur and are eaten in large numbers under the guise of marsh rabbit. If infected, they transmit tularemia to the one who skins them. Skunks are skinned for furs. If

they happen to have tularemia they pass it on to the person who skins them. Coyotes contract tularemia from the infected rabbits which they eat. Man becomes infected when skinning an infected coyote.

Certain animals are rabbit eaters If they should eat an infected rabbit and immediately bite a man the infection which lurks in their mouths and about their teeth is conveyed to people whom they bite People have contracted tularemia from the bites of cat, skunk, coyote, Montana ground squirrel, opossum, dog or hog. Two people were scratched by cats and another was scratched by a tree squirrel.

Human cases have been recognized in forty-six states of the United States and in the District of Columbia The only states which have not recognized cases are Vermont and Connecticut The disease was reported in Japan in 1925, in Russia in 1928, in Norway in 1929, in Canada in 1930 and in Sweden in 1931. No other country has recognized the disease.

CASES REPORTED IN THE UNITED STATES

	Cases	Deaths
Previous to 1924	15	2
1924, 1925 and 1926	308	11
1927	251	10
1928	350	10
1929	462	36
1930	659	37
1931	675	32
1932	933	41
1933	1021	
	3,653	179

The disease was named tularemia after a county in California—Tulare County—where it was first discovered in 1910 by Dr. George W. McCoy, of the United States Public Health Service The disease therefore bears the label "Made in America," and it has been elucidated from beginning to end by American investigators alone.

COMPARATIVE VALUES OF AMERICAN MAMMALS, 1726 AND 1753

By LEILA G. FORBES and HUGH UPHAM CLARK

WASHINGTON, D. C.

THE sharp rise in the prices of our natural products and of imported commodities between the years 1726 and 1753 is well brought out by an interesting official document from the early records of the Province of the Massachusetts-Bay in New England which is now in our custody.

This document, given in full herewith, shows the increase in value of the more important native mammals, and also of the more important articles of trade. We have given the latter in order that they may be compared with the former.

The Treaty at Casco in 1726 referred to was the Conference between Lieutenant-Governor William Dummer of the Massachusetts-Bay in New England and others, and the Eastern Indians, held from July 16 to August 11, 1726. The proceedings of this conference are printed in full in the Collections of the Maine Historical Society, Portland, Maine, Vol. 3, 1853, pp. 377–405.

The conference was for the purpose of ratifying the treaty of peace drawn up at Boston in the preceding winter. This treaty, "Dated at the Council-Chamber in *Boston* in New-England, December 15, 1725," was printed by Samuel Penhallow in his "History of the Wars of New-England with the Eastern Indians," etc., Boston, 1726. In it we read (p. 124) "That all Trade and Commerce which may hereafter be allowed betwixt the *English* and the Indians shall be under such management and Regulation, as the Government of the *Massachusetts* Province shall direct."

In the proceedings of Friday, August 5th, 1726, we find (p. 394):

Lt. Gov. of the Massachusetts. The Articles of the Treaty shall be distinctly read, and faithfully Interpreted to you.

While the Articles were in Reading, Immediately after the Article respecting Trade, the Indians by their Speaker *Loron*, acquainted the Lieut. Governour that they had been told the Prices of Goods would be raised when the Ratification was over.

The Lieut Governour answered them, that they might be assured, that the Goods always were, and still should be, bought with ready Money, and that the Government would not make any new Advance on their goods, and for a Proof of it, they would always be sensible and find that the Government would supply them Cheaper than any other People whatsoever, That they are Acquainted with the Nature of Markets, that they are sometimes higher and sometimes lower.

After the Articles were read, and the Interpreters had finished, *Loron* made a second motion, and informed the Lieut. Governour, that it had been reported that the Articles of Peace which were delivered to him, and the other Delegates at *Boston*, were not of the same Purport with those they Deposited and left in the Hands of the Government, and therefore desired that an Exchange might be made of the Articles they carried with them to *Penobscut*, with those left in the Hands of the Government, in order to their being Enabled to confute such Reports: Which was readily granted them by the Lieut. Governour, to the apparent Satisfaction of the whole Tribe. The Articles being Interpreted to the Indians, the Lieut. Governour asked them whether they thoroughly understood them.

Indians. We perfectly understand them all.

The document bears on the back the annotation—

"Publick Papers
Indian Affairs
1726.1753"

PRIZES OF FURS, ALLOWED THE JNDIANS, IN THE YEAR 1726 WHEN L[T] GOVERNOR DUMMER HAD A TREATY AT CASCO AND WHAT THE JNDIANS THEN PAID FOR THEIR GOODS IN LIEU THEREOF, WITH WHAT'S ALLOW'D THEM AT PRESENT FOR THEIR FURS, AND AN ACCOUNT OF WHAT THEY NOW PAY FOR GOODS IN EXCHANGE

Prizes of Goods sent the Jndians in 1726	Prizes of Goods sent the Jndians in 1753	Prizes of Furs & Beaver purchas'd of y[e] Indians in the Year 1726	Prizes of Furs allow[d] the Indians in the Year 1753
Rum 5/ pr Gallon	16/ pr gallon	Spring Beaver 8/pr plus	40/ pr plus
Bread 50/ pr hund[d]	£9 pr hundred	Fall Ditto 6/ pr plus	25/ pr plus
Corn 6/ pr bushell	28/ pr bushell	Stage Ditto 4/ pr plus	15/ pr plus
Pipes 6/ pr Groce	30/ pr Groce	Fishers 6/ piece	40/ piece
Tobacco 10[d] pr pound	3/ pr pound	Catts 6/	25/
Oznabngs 2/9 pr Ell	10/ pr Ell	Ottors 6/	40/
½ thicks 4/6 pr Yard	15/ pr Yard	Minks 20[d]	8/
Blankets 21/ apiece	£4 apiece	Bears Large 3/6	25/
Hatchets 5/6 apiece	20/ apiece	Musquash 4[d]	3/
Molasses 3/8 pr Gall[o]	14/ pr gallon	Castorum 2/ pr plus	15/ pr plus
Broad Cloth 33/ pr yard	£4 pr yard	Moose 10/ piece	50/ piece
Strouds £17 apiece	£60 apiece		
Pork £7 pr barrell	£25 pr barrell		
Kegs 2/ apiece	5/ apiece		
Shot 78/ pr hund[d]	£12 pr hund[d]		
Powder 18£ pr bb	£50 pr barrell		

Septem[r] 15[th] 1753
Errors Excepted
pr Jn[o] Wheelwright

Explanation of Terms

Bear—The black bear, *Euarctos americanus* (Pallas).

Beaver.—*Castor canadensis* Kuhl.

Castorum—A reddish brown substance consisting of the preputial follicles of the beaver and their contents dried and prepared for commercial purposes It has a strong, penetrating, and persistent odor and was formerly in high repute as a medicine, later being used chiefly for perfumes.

Catts.—*Lynx canadensis* Kerr and *L. rufus* (Schreber).

Fisher.—*Martes americana* (Turton) or *M. pennanti* (Erxleben).

Half-thick.—A kind of coarse cloth. Mr. J. Leander Bishop mentions half-thicks among the large quantities of different kinds of cloth imported in colonial days from England (A History of American Manufacturers from 1608 to 1860, Philadelphia, 1861, p 344)

Mink.—*Mustela vison* Schreber

Moose.—*Alces americana* (Clinton).

Musquash—The musk-rat, *Ondatra zibethica* (Linne)

Ottors—Otters; *Lutra canadensis* (Schreber)

Osnabngs—Osnaburgs; osnaburg was a coarse cloth made of cotton, or of flax and tow, first manufactured at Osnaburg in Germany.

Plus.—According to Dr. Hartley H. T Jackson this is the value, or equivalent, of one prime beaver skin.

Strouds.—A stroud was a blanket made of strouding, a coarse warm cloth, used in trading with the Indians.

BUST OF PROFESSOR ALBERT EINSTEIN

EXECUTED BY JACOB EPSTEIN, PRESENTED TO THE HEBREW UNIVERSITY BY HIRAM J. HALLE, OF NEW YORK CITY, ON THE OCCASION OF THE DEDICATION OF THE EINSTEIN INSTITUTE OF PHYSICS.

THE PROGRESS OF SCIENCE

THE EINSTEIN INSTITUTE OF PHYSICS AT JERUSALEM

IN 1924 a long procession of motor-cars wound its way up Scopus, "the mount of gazing," just outside Jerusalem, where the first scientific address was to be delivered under the auspices of the infant Hebrew University whose formal dedication by the late Earl Balfour was not to take place until the following April Crowds of peasants had collected from the neighboring Arab villages in order to see and hear one of the greatest scholars in the world, Professor Albert Einstein

Two years were to elapse after that first lecture on physics until, in 1926, in connection with the visit of Dr Leonard Ornstein, well-known physicist and rector of the Utrecht University in Holland, it was definitely decided to establish an Institute of Physics at the Hebrew University, which last month was dedicated as the Einstein Institute of Physics in the presence of a distinguished group of governmental officials, academic staff and student body of the Hebrew University and visitors from America and abroad.

A bust of Dr. Einstein executed by the American sculptor, Jacob Epstein, and presented to the institute by Hiram J. Halle, of New York City, forms one more link between the great scientist and the university which has the honor of having as one of its rarest possessions the original manuscript on "The Theory of Relativity," a gift of Dr. Einstein.

Situated on a steep slope of the northeastern boundary of the university grounds, which themselves overlook all Jerusalem, the Einstein Institute commands probably the most historic view of which any campus can boast. The eye roams as far as the Jordan Valley and the deep basin of the glittering Dead Sea; across the intervening bowl of the Jericho foothills, lying below the Jerusalem range, loom the purple mountains of Moab. Stately old trees surround the institute, all the more remarkable in a land laid waste and barren through centuries of warfare.

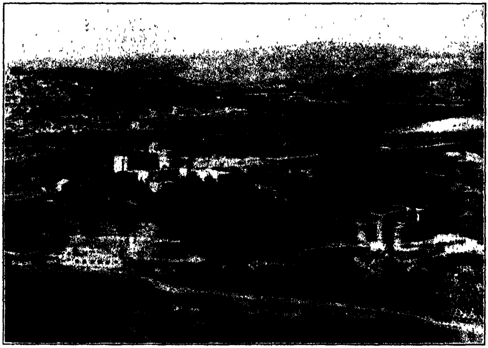
The new Institute of Physics is not designed merely to fill an urgent need of the university as such, even though the methods applied to physics are beginning to enter into every branch of scientific investigation; it is of equal importance for the general research work which is going on all over Palestine It will house the first materials testing laboratory in Palestine, a factor of extreme importance in a country with such intensive building activity, where hitherto no facilities have existed for examination and testing of building materials by scientific methods The institute will be called upon to solve certain questions which can be answered there better than elsewhere on account of its varied climatic conditions For example, an astrophysical observatory, which would carry on its work under exceptionally favorable conditions, is to be attached to the spectroscopical laboratory Few countries have so transparent an atmosphere as Palestine. As in more northern latitudes the air has little dust and, in contrast to the tropics generally, is free from moisture For the greater part of the year the sky is cloudless and presents a picture of undimmed radiance. Moreover, there is no other observatory in the whole of the Near East The nearest on European soil is at Athens.

Dr. Ornstein, who is a member of the board of governors of the Hebrew University, supervised the plans for the construction of building along the lines of the most up-to-date European institutes. In November, 1928, building operations commenced, culminating in the present U-shaped building, which was dedicated on March 11. The cen-

tral portion contains two stories and a basement. There are also two wings of one story each. Classrooms, lecture rooms, offices, photograph rooms, battery and dynamo rooms, five research laboratories and a basement for spectroscopic experiments are included. Announcement was made at the dedication exercises that work has already been commenced on one of the two wings

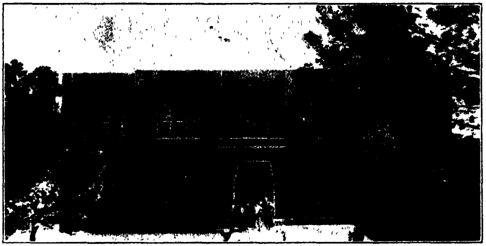
It is interesting to note that two women, Mrs. Helena Davis, of London, England, and Mrs. Dora Monness Shapiro, of New York City, have made these two wings possible. Each of them this year has contributed funds for the erection of further laboratories. Mrs Shapiro and her late husband were responsible with Philip Wattenberg, also of New York City, for the erection of the original building at a cost of approximately £15,000 and for a ten-year maintenance fund for the entire building. Construction of the second wing of the building will be complete and two additional laboratories and offices will be available for extended research and instruction. The new Abraham and Helena Davis Laboratory will be used in connection with further accommodation needed for the increased number of students in the Division of Biological Studies.

The present equipment is modest and in keeping with the youth of the university as a whole. This month marks the ninth anniversary of this "first University of the Jewish people." Great tasks



AERIAL VIEW OF THE HEBREW UNIVERSITY ON MT. SCOPUS

IN THE FOREGROUND OF THE PICTURE MAY BE SEEN THE JORDAN VALLEY LYING 3,000 FEET BELOW THE STAGE OF THE MINNIE UNTERMYER MEMORIAL OPEN-AIR THEATER. ON THE OTHER SIDE IN THE REAR IS THE DAVID WOLFSOHN MEMORIAL LIBRARY, OVERLOOKING THE OLD CITY OF JERUSALEM. THE UNIVERSITY IS SITUATED ON MT. SCOPUS, PART OF THE RANGE OF THE MOUNT OF OLIVES. AT THE RIGHT FOREGROUND, BACK OF THE NEWLY PLANTED FOREST, IS SHOWN A REAR VIEW OF THE EINSTEIN INSTITUTE OF PHYSICS.



THE ENTRANCE TO THE EINSTEIN INSTITUTE OF PHYSICS

await the scientific scholars who will take up their work in this building on the edge of the desert, named for the greatest physicist of our times.

A new and important step in the development of science in the Near East has been taken—in the beautiful and lucid words of the Bible, "Migdal Zofim al Har-ha-Zofim," meaning "A watch tower has been erected on the Mount of Gazing," Mount Scopus.

J B. K

THE HEAVY HYDROGEN SYMPOSIUM AT THE ST. PETERSBURG MEETING OF THE AMERICAN CHEMICAL SOCIETY

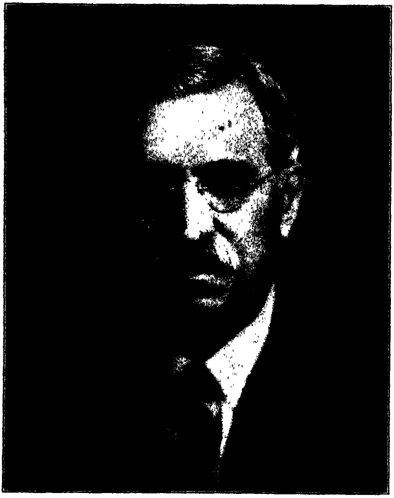
On March 27 at St. Petersburg, Florida, the members of the American Chemical Society held a meeting to discuss the chemistry of the latest addition to the chemical family of elements, the so-called "heavy hydrogen."

The search for this substance was begun about fifteen years ago, when Stern and Volmer and W. D. Harkins made unsuccessful attempts to find evidence for it. In 1930 Allison and his co-workers reported results in their studies with the magneto-optic method, which pointed very strongly to the presence in hydrogen compounds of an isotope of hydrogen with atomic weight two. At about the same time Birge and Menzel concluded from a study of atomic weights that such an isotope should exist.

In 1932 Urey, Brickwedde and Murphy provided final and indisputable proof of the isotope by concentrating it through the evaporation of liquid hydrogen. Thus it became apparent that a new and very important chapter of chemistry had begun.

The next important step was taken by E. W. Washburn, late chief chemist of the Bureau of Standards, working in collaboration with Professor Urey They showed that a fairly rapid concentration of heavy hydrogen occurred when water was electrolyzed into hydrogen and oxygen.

This fact was then utilized by Dr G N. Lewis, of the University of California, through a series of electrolyses to bring about the first separation of a large amount of heavy hydrogen into something approaching the pure state. Following Lewis's demonstration that heavy hydrogen can thus be prepared, a large number of workers have made heavy hydrogen and are busy studying its chemical and physical properties.



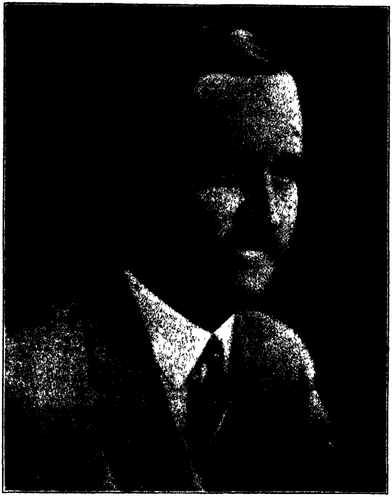
DR. CHAS. L. REESE

RETIRED CHEMICAL DIRECTOR OF E. I. DU PONT DE NEMOURS AND COMPANY, PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY.

These historical facts were reviewed in the opening paper of the symposium by Professor Urey, who also described the work on heavy hydrogen now being carried on at Columbia University.

The second paper on the program was given by Dr. Brickwedde, director of the Cryogenic Laboratory of the Bureau of Standards, at which the discovery of heavy hydrogen was made in collaboration with Professor Urey. Following up the initial discovery, Dr. Brickwedde prepared pure heavy hydrogen in the liquid form and measured its boiling point and other important physical properties.

The third paper was given by Professor H. S. Taylor, of Princeton University, and described the work which has been carried on in the chemistry laboratory at that institution on various problems regarding heavy hydrogen. This laboratory was the first to put into operation a plant for the large scale manufacture of heavy hydrogen, and Professor Taylor and his co-workers have contributed many valuable ideas in connection with the theory and practice



PROFESSOR ROGER ADAMS

HEAD OF THE DEPARTMENT OF CHEMISTRY AT THE UNIVERSITY OF ILLINOIS, WHO HAS BEEN ELECTED PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY FOR 1935

of separating the isotopes. They are particularly interested in the use of heavy hydrogen as a tool for investigating the nature and rate of chemical reactions.

It is particularly useful in this respect because it may be employed in reactions which have been studied extensively with ordinary hydrogen and the change to heavy hydrogen changes only the factor of mass, leaving everything else constant. The workers at Princeton have synthesized ammonia in which heavy hydrogen replaces ordinary hydrogen and find that the properties of this ammonia are quite different from those of the ordinary kind

The fourth paper was given by Professor G. H. Dieke, of the department of physics of the Johns Hopkins University, and was a review of the spectroscopy of molecules containing heavy hydrogen. The introduction of heavy hydrogen into compounds such as ammonia and methane, one of the principal constituents of coal gas, gives these molecules the power to absorb light to which they are otherwise transparent.

The fifth paper was given by Professor Fred Allison, of the Alabama Polytechnic Institute. Professor Allison has developed an apparatus based on the magneto-optic effect, which enables the detection of very small amounts of the different chemical elements He has applied this to the study of heavy hydrogen with extremely interesting results In fact, he brought forward evidence for the existence of this substance some time before Professor Urey discovered that it was possible to concentrate it and thus prove its existence beyond any question of doubt. Allison has recently confirmed the results reported by Professor W. M. Latimer and Dr. Herbert A Young, of the University of California, which indicate the possibility that a type of hydrogen exists in which the atom has the mass three.

The afternoon session of the meeting was devoted to papers of a more specialized nature, dealing with phases of the problem which have been studied recently. A paper by the late Dr. E. W. Washburn and Edgar R. Smith was read on the separation of heavy hydrogen by the vital processes in a growing willow tree.

Dr Leigh C. Anderson, Dr. J. R. Bates and Dr. J. O. Halford, of the University of Michigan, have developed a means of preparing heavy hydrogen by the continuous flow of water through a long trough in which a number of electrodes are placed. They have used the heavy hydrogen so prepared for studying a number of organic chemical reactions.

Messrs. D. H. Rank and G. H. Fleming, of the Pennsylvania State College, have prepared a compound of carbon and heavy hydrogen, so-called neopentane, which shows the great effect produced on the spectrum of the compound by the substitution of heavy hydrogen for ordinary hydrogen. Professors D. Rittenberg and Urey at Columbia University have studied the reactions between iodine and heavy hydrogen with important theoretical results.

Dr. P. W. Selwood, of Princeton University, read a paper on the specific gravity of mixtures containing heavy hydrogen.

Professor N. F. Hall, T O. Jones and E. Bowden, of the University of Wisconsin, reported that heavy hydrogen has a great tendency to exchange place with ordinary hydrogen in a number of materials. For this reason, if one has a compound containing heavy hydrogen great care must be exercised in placing it in contact with ordinary water or other compounds containing ordinary hydrogen.

Dr. B. Topley and Dr. H. Eyring, of Princeton University, read papers on the theoretical aspects of the subject. Dr. Topley found that the fact that heavy hydrogen will separate in electrolysis is due not to diffusion, but to certain differences between heavy and light hydrogen which affect the so-called quantum mechanics of the reaction.

Dr. Eyring's paper pointed out that the study of water containing heavy hydrogen gives important insight into the nature of this universally useful substance. It indicates that the water molecules can rotate freely in the liquid.

Besides the symposium on "heavy hydrogen" a number of other interesting papers were read before the meeting on topics of general chemical interest. Dr. M. T. Bogert gave an address entitled "Your Nose Knows," dealing with the chemistry of perfumes. Papers of interest to the industrial chemists were read by Dr. C. H. Herty on "Pine Products," E. L. Smith on "Chemical Securities," E. E. Ware on "The Trend in Protective Coatings" and W. H. Dow and L. C. Stewart on "The Commercial Extraction of Bromine from Sea Water." The pleasant surroundings at St. Petersburg, together with the beautiful Florida weather, made the meeting one of the most enjoyable which the society has held.

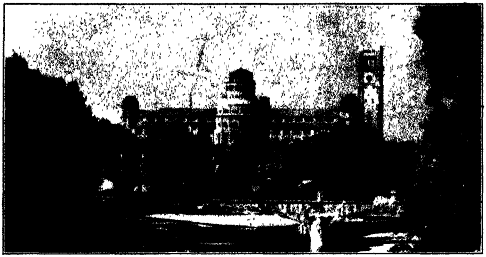
DONALD H. ANDREWS

OSKAR VON MILLER

THE news that Dr. von Miller died in Munich on April 8 at the age of seventy-eight (he would have been seventy-nine on May 7) will be received with regret by scientists and engineers all over the world. Although he was known chiefly as the creator of the famous Deutsches Museum he had made an international reputation for himself as a pioneer in electrical engineering.

After graduating from the Polytechnikum of Munich von Miller entered the service of the Bavarian government. At the Paris Electrical Exposition of 1881, whither he went to broaden his technical knowledge, the sight of electric incandescent lamps and dynamos exhibited by Edison, of streets illuminated by arc lamps, of telephones, of motors that drove machines so overwhelmed him that on his return he organized the Munich Electrical Exposition of 1882, the first held in Germany. There he demonstrated the much-doubted feasibility of transmitting electric energy over an experimental line of telegraph wire stretched between Miesbach and Munich, a distance of 57 kilometers.

Joining Emil Rathenau in 1883 in founding the German Edison Company



THE DEUTSCHES MUSEUM

von Miller designed the first central station of Berlin and formally opened it on September 13, 1884. The company later became the Allgemeine Elektrizitätsgesellschaft. Although he could have remained with the organization he preferred to open his own offices in Munich. As the technical director of the Frankfurt Exposition of 1891 he boldly demonstrated the practicability of transmitting alternating current a distance of 180 kilometers at 25,000 volts between Lauffen and Frankfurt from a 300-horsepower hydraulic plant. His success created an international technical sensation and established his reputation. Thereafter he was much in demand as a consulting engineer in developing the water power of his native Bavaria and expanding the electrical network of the old empire. He must be numbered among the daring technical pioneers in practically applying electric energy.

It was in 1903 that von Miller laid before the representatives of German industry the plan of a museum which was not only to preserve the masterpieces of engineering and science, but to teach technology with the aid of sectioned models that could be thrown into operation by any visitor merely by pushing a button or pulling a lever. The proposal was received with acclamation. In a year the now famous Deutsches Museum of Munich was actually in existence, housed in the abandoned National Museum. In the new building, which was erected on an island in the Isar and which was ceremoniously opened in 1925, some 60,000 objects of scientific and technical interest are displayed. Over a million visitors annually walk about ten miles through these exhibits, operating those that have moving parts and studying the dioramas and paintings. To this imposing structure von Miller added a *Studienbau* or technical library, with lecture halls

Although the Conservatoire des Arts et Métiers of Paris and the Science Museum of South Kensington are both older than the Deutsches Museum there can be no doubt that von Miller revolutionized museum practise. So far as he could he abandoned glass cases. Attendants were to be not watchdogs but aids. The visitor was to handle and operate anything within reason, and if this was impracticable, as in the case of a locomotive, he was to summon a trained guard to assist him. Instead of a storehouse of historic relics the Deutsches

Museum is an institution where the rudiments of science and technology may be acquired by any intelligent visitor. The lesson was so dramatically effective that older technical museums soon followed von Miller, and American philanthropists were inspired to lay plans for similar dynamic technical museums in Chicago, New York and Philadelphia.

WALDEMAR KAEMPFFERT

HAZARDS TO AIRCRAFT DUE TO ELECTRICAL PHENOMENA

NUMEROUS suggestions, including various fanciful ideas, have been presented in press notices or otherwise, to explain by means of great electrical forces the destruction or injury which has occurred from time to time of huge airships and other types of aircraft exposed to thunderstorm conditions. In order to secure a fair appraisal by experts of the merits of such suggestions and to ascertain if further investigations were advisable, the National Advisory Committee for Aeronautics, upon the request of one of the federal agencies responsible for the operation of airships, appointed a special committee to consider and report upon the general question of hazards to aircraft, both airships and airplanes, due to electrical phenomena.

This committee was composed of the following members: Dr. L. J. Briggs, Bureau of Standards; Commander Garland Fulton (C. C.) U. S. N.; Dr. W. J. Humphreys, Weather Bureau; Dr. J. C. Hunsaker, Massachusetts Institute of Technology; Dr. F. B. Silsbee, Bureau of Standards; Professor John B. Whitehead, The Johns Hopkins University; Mr. G. W. Lewis, National Advisory Committee for Aeronautics (*ex-officio*), and Dr. Charles F. Marvin, U. S. Weather Bureau, *chairman*.

The committee profited in its study of the problem by the assistance of Dr. M. F. Peters, of the Bureau of Standards, and was also guided by a prior confidential report on the same question by a British authority and by reports of recent German investigations. It is believed confidence is justified in the unanimous conclusions of the committee, herein briefly presented under two types of electrical influence.

ELECTROSTATIC ATTRACTION OF AIRSHIP TO EARTH

Alleged estimates of the magnitude of such forces by various authors differ from a few ounces to many tons. Large airships consist of a huge cage of closely bonded metallic and electrical conducting framework, with thin fabric or metal covering and numerous fabric gas cells enclosed in more or less closely meshed wire netting. When floating in the atmospheric electric field between the earth and the clouds, the ordinary processes of electrostatic inductions tend to separate the positive and negative electrical charges on such an object, and if, for example, the negative charges were partially or wholly dissipated, the structure would tend to be drawn down to the earth below by the electrical attraction.

Dr. Simpson, of the British Meteorological Office, from a careful analysis of the probable magnitude of this attraction on a large airship, places it at a *few hundred pounds*. Even assuming that in extreme cases the atmospheric field might be of higher intensity than used in Dr. Simpson's calculations, our committee was convinced that the forces due to electrical attractions between an airship and the ground can not rise to dangerous values.

The possibility of the accumulation of high values of electrostatic charge due to the fall of positively charged rain was also reviewed. A high positive charge on the ship by falling rain is possible, of course, only provided little or none of the accumulated charge escapes. The continuous escape of such charges is, however, greatly facilitated by several causes. In the first place, after a short

time as much rain must fall away from the airship, carrying off its charge, as falls upon it. Many exposed metallic points of short radius of curvature all over an airship tend to dissipate any great accumulation of electrical charge. Finally, the highly ionized condition of the exhaust gases from the engines of airships in flight also dissipate electrical charges.

It was concluded that the maximum possible attractive forces due to rain or other sources of electrification were about of the same order of magnitude as in the case of those possible by ordinary electrostatic induction.

That airships in flight do become somewhat highly electrified is shown by the cases of shock to men grasping mooring ropes. The actual magnitude of such charges is shown to be moderate because no such shocks have been fatal.

All these considerations seem conclusively to indicate that the forces of electrical attraction between aircraft and the earth can not attain sufficient magnitude to be hazardous in themselves.

High-Frequency or Steep-Wave-Front Lightning Discharges

A possible type of electrical hazard may arise from the existence in proximity of an airship of very high frequency electrical discharges, and while actual lightning strokes are not strictly high frequency discharges in this sense, nevertheless it is pointed out that the very steep wave front which may characterize the tumultuous rush of a violent stroke of lightning may itself be the origin of effects resembling those due to true high frequency discharges. The hazards due to electrical influences of this character arise from relatively small secondary sparks which may possibly occur within the structure of the aircraft itself and may puncture gas bags or possibly ignite inflammable gases or other material.

A high degree of internal protection from the hazards is automatically provided by the bonded metal framework of either an airplane or an airship. This protection is based upon the well-known electrical principle of the Faraday cage and is more effectual in an all-metal airplane than one in which wood and fabric are used. In the airship the protection is greater the closer the meshes of the metallic framework and the wire bracing, and the smaller the mesh of the wire netting enclosing the gas bag. Further protection is assured whenever the surface of the outer envelope is a good electrical conductor. While it is possible for a direct lightning stroke to damage an airship by passing between meshes of the framework, past experience affords no evidence of the occurrence of such phenomena, and grave doubt that it occurs as a dangerous hazard is justified. Furthermore, the committee does not find sufficient evidence of the existence of disturbances of this character to warrant a program of experimental study

In this connection, it is known that trailing radio antenna and cables used in suspending observers may facilitate direct lightning strokes. However, protection from such hazards is afforded during thunderstorm conditions by reeling in the observer's cable and antenna or the use of other types of antenna.

Storm Areas Should be Avoided

When proper precautions are taken, and when the customary protective methods inherent in bonded metallic cage construction are utilized, the committee considers the probability small that serious damage from electrical charges and discharges will result. But even though neither airplanes nor airships are in much danger from lightning, both must make every effort to avoid thunderstorms—must keep out of the exceedingly violent and extremely turbulent winds of thunderstorms which cause great danger of destruction.[1]

Charles F. Marvin

[1] The report in full is being published as a Technical Note by the National Advisory Committee for Aeronautics.

THE SCIENTIFIC MONTHLY

JUNE, 1934

ATOMS[1]

By Dr. PAUL R. HEYL

PHYSICIST, NATIONAL BUREAU OF STANDARDS

MATTER is at once the most familiar and the most puzzling thing in the universe. Many speculations as to its ultimate nature have been made and discarded. The twentieth century, apparently despairing of explaining it, has explained it away by making it merely another aspect of that Protean concept, energy. Yet though we can not answer the question "What is matter?" we may still find it profitable to consider its physical structure, for this is something about which we have been able to learn much by experiment.

Two opposite views of the structure of matter are possible, and both have been held since ancient times. We need know nothing of the ultimate nature of matter to recognize that it must be either as continuous as it appears to be or else discontinuous, but of so fine a grain as to elude our observation. In that Great Age of Greece centering around 400 B.C. we find philosophers holding both theories of the structure of matter. The continuous theory was maintained by Anaxagoras and Aristotle, while the existence of atoms was upheld by Democritus and Epicurus.

The antiquity of the atomic concept is sometimes cited as an instance of the keenness of thought of the ancients, much as if they had made by the unaided intellect a discovery which in modern times has received much experimental attention. We must be careful, however, not to over-rate the ancients in this respect. Neither theory as held by them had anything which we to-day would call an experimental basis; both were equally pure speculation. It does not require an exceptional intellect to formulate two alternatives when there is no evidence for or against either. The modern crank, who ignores or is ignorant of experimental facts, can spin out of his inner consciousness hypotheses in profusion. Ancient science is frequently disappointing. The ancient philosophers guessed at the causes of phenomena but often stopped there. We of to-day guess also, but we check our guesses by experiment.

It can not be urged that experiment was altogether impracticable for the ancients. There may be mentioned two accepted doctrines of antiquity, the falsity of which might have been shown by experiments simple enough to be possible at any time or place, yet which no one seems to have thought of carrying out.

The first of these is the dictum of Aristotle that heavy bodies fall with speeds proportional to their weights. It is remarkable that with the exception of one fruitless and soon forgotten criticism of this dictum, made by a philosopher of the sixth century A.D.,[2] there is no record of any other skeptic until the time of

[1] Publication approved by the director of the Bureau of Standards of the U. S. Department of Commerce.

[2] John Philoponus, cited by Heidel: "The Heroic Age of Science," p. 187. Baltimore: Williams and Wilkins Company, 1933.

Galileo, two thousand years after Aristotle.

The second of these erroneous notions is embalmed in our word "crystal," which comes from a Greek word meaning ice. The ancients knew quartz in the form of rock crystal, but in their experience this mineral was found only in certain elevated mountain regions where the cold winter was intense and long continued They believed it to be water which had been permanently frozen by this extreme cold. Apparently no one ever thought of leaving a vessel of water to pass the winter in these regions—or was willing to take the trouble.

While perhaps no particular credit is to be assigned to those ancient philosophers who suggested that matter was discontinuous in structure, the idea was thus placed on record, to be taken up again centuries later But all through the Middle Ages, due to the ascendency and authority of Aristotle, the continuous theory was supreme. The discontinuous or atomic theory is to-day so familiar and generally taken for granted that it is difficult to imagine any other hypothesis as worthy of serious consideration, yet the opposite theory continued to have its advocates down to quite recent years. Among these may be mentioned T. Sterry Hunt, the chemist and geologist, who died in 1892, and the still better known name of Ernst Mach, of Vienna, who lived until 1916. The atomic theory, though of a respectable antiquity, has had a long struggle for acceptance. Its final victory presupposes some rather cogent experimental evidence in its favor, which it may be of interest to set forth and consider. Of this evidence we may distinguish four independent lines which we shall discuss in their historical order.

The atomic theory of matter began to regain favor with the birth and growth of experimental science after the revival of learning. Perhaps the Roman poet Lucretius, who shared the renewed interest of the learned world of the Renaissance in the classic writers, had a share in the revival of the atomic theory, for he was an earnest upholder of this view. But the principal reason for the revival of the atomic theory was general rather than precise and specific. With an increasing knowledge of the phenomena of nature many things were found to be more simply explainable on the discontinuous theory The expansibility of gases and the great change in volume from water to steam stretched the continuous theory to the breaking point, while on the alternative theory it was necessary merely to suppose that the particles of steam were farther apart than those of water Boyle and Newton believed in the existence of atoms though they used the term rather loosely, and in many cases where we would say "molecule." The modern distinction between atoms and molecules was not clearly established until the middle of the nineteenth century.

This general line of reasoning, of course, did not satisfy everybody There were, as we have said, skeptics throughout the nineteenth century But the atomic concept by the year 1805 had so far reestablished itself as good form that Dr. Thomas Young offered no apology for attempting to determine the size of a molecule.

The second line of evidence for the existence of molecules and atoms is of a chemical nature It was put forward by Dalton in the early years of the nineteenth century. So great was the impetus which Dalton gave the subject that he has been called "The Father of the Atomic Theory." What he did to warrant that title was something characteristic of the nineteenth century. he made the theory quantitative.

Dalton introduced the idea of atomic weights, a definite weight for the atom of each element. He appears, on the evidence of his manuscript note books,[3]

[3] Roscoe and Harden, "A New View of the Origin of Dalton's Atomic Theory," Macmillan and Company, 1896.

to have been led to this by physical rather than chemical considerations, such as the diffusion of gases and the varying solubility of different gases in water. By a study of these phenomena he was led to the concept of a difference in the size of the molecules of various gases From definite sizes it was an easy step to the idea of definite weights characteristic of each substance This explained much with regard to quantitative chemical combination, and appears to have been the origin of his laws of definite and multiple proportions

These laws of Dalton, whatever may have been their origin, rest securely upon the results of chemical analysis They follow at once from the assumption of the combination of atoms with atoms, while on the continuous theory there is no simple explanation of the results of experiment As Dalton himself said· "The doctrine of definite proportions appears mysterious unless we accept the atomic hypothesis." And again "It appears like the mystical ratios of Kepler, which Newton so happily elucidated." With the later development of analytical technique, especially at the hands of Berzelius and of Stas, the atomic theory reached a high degree of probability.

In the year 1827 there was made a discovery which was destined to furnish a third independent line of evidence for the reality of molecules. The full development of this evidence, theoretical and experimental, required eighty years for completion. In 1827 Robert Brown, a British botanist, was investigating the pollenation of plants, and had occasion to observe under the microscope minute grains of pollen suspended in water He noticed that even under the best observing conditions these grains were never at rest, but vibrated slightly and irregularly about a mean position. This phenomenon has since been known as the Brownian motion.

[4] *Phil. Mag.*, 4: p. 161, September, 1828; 6: p. 161, September, 1829.

Brown's original paper[4] is most interesting reading. It reveals the working of a mind essentially logical and scientific, albeit hampered in one respect by a traditional intellectual fetter. Brown first satisfied himself that the motion was not due to the vibration of his apparatus nor to convection currents nor to evaporation of the liquid. He observed the motion in drops of water suspended in oil, which completely prevented evaporation, and found that the motion continued for many days, while differences of temperature should have equalized themselves in a comparatively brief time

Among these grains of pollen Brown noticed smaller particles of a roughly spherical form which showed a more brisk vibration than the larger grains. These smaller particles he called "active molecules."

There was current in biological circles at that time a theory that there was an ultimate element or atom of life, an idea which some dozen years later was merged into the concept of the newly discovered cell as the biological unit. Brown appears to have believed at first that in his active molecules he had found these atoms of life. He had satisfied himself that the motion was not due to extraneous causes such as vibration or convection currents, but appeared to be a characteristic of the particles themselves, and as the particles were derived from a living plant it was but natural that he should have reached the conclusion that their motion was in some way due to life.

To check this conclusion he killed a plant by steeping it for several days in alcohol Much to his surprise he found that he could extract from this dead plant active molecules of apparently undiminished vitality. It then became of importance to determine how long these particles would retain their vitality after the death of the plant.

From a herbarium Brown obtained a specimen which had been twenty years in the collection, and from this he ob-

tained active molecules. Another specimen which had been in the collection for a century gave the same result. It was then obviously necessary to work with material of geological age, and specimens of lignite and bituminous coal were tried, in each of which active molecules were found. Surprise was added to surprise when Brown found that the London soot seemed to be composed almost entirely of active molecules, though it had but recently been through the fire.

Brown their tried a piece of petrified wood. He knew that in this substance the wood fiber had been entirely replaced by silica, but he thought it possible that some active molecules might have lingered behind. He found, in fact active molecules in surprising abundance.

This led Brown to experiment with materials which, as far as was known, had never been living, such as specimens of British granite, and again the active molecules were in evidence. Finally, to obtain a specimen of undoubted antiquity, he tried a chip taken from the Sphinx!

This test was not as childish as it may seem to-day. In 1827, and indeed for many years after, the whole of Western Christendom, learned and unlearned, was still under the spell of Archbishop Usher's chronology, which assigned to the Creation the date 4004 B.C. To question this was in those days no laughing matter.

The universal presence of these active molecules was a mystery which Brown did not attempt to explain. A later writer[5] (1863) says that Brown was of the opinion that these particles of elementary life, existing everywhere, might bridge over the gap between the living and the non-living, the idea apparently being that in some substances these active molecules lay dormant but eternal, while in others they developed into living organisms.

Brown's discovery attracted but little attention at the time. It was generally thought that this motion must be in some way similar to the dancing of motes in a sunbeam, in spite of the care that Brown had taken to eliminate the explanation of convection currents. It was not until 1863, when the concept of atoms and molecules had become well established, and a beginning had been made in the kinetic theory of heat, that Wiener[6] suggested the explanation now generally received—that the motion of these particles was the result of the impacts of the molecules of water, much as a swiftly moving bullet may produce a slight motion in a much heavier cannon ball.

Wiener's suggestion attracted in its turn but little attention. Some fifteen years later Delsaulx and Carbonnelle[7] again put forward the same explanation with an important addition. It was apparent to Carbonnelle that the impacts of the water molecules would occur in such rapid succession that they could not produce any perceptible disturbance of a large particle, the successive impacts nearly cancelling out on the whole. But Carbonnelle pointed out that if the surface of the suspended particle was small enough it might be that the irregularities would no longer compensate; that there would be a perceptible resultant which would change continually in intensity and direction. In consequence, the smaller the particle the more brisk should be its vibration. It will be remembered that this is just what Brown observed with the pollen grains and the smaller particles which he called active molecules.

These suggestions seem to have attracted as little attention as that of Wiener, but in 1888 Gouy[8] published an account of experiments on this subject which for some reason attracted wide attention. From this time the Brownian

[5] Wiener, *Pogg. Ann.*, 118: p. 79, 1863.

[6] *Ibid.*

[7] See an article by Thirion, *Revue des Questions scientifiques*, January, 1909.

[8] Gouy, *Journal de Physique*, 7: p. 561, 1888; *Comptes rendus*, 109: p. 102, 1889.

movement was recognized as an important physical problem.

The next important step toward its explanation came with the early years of the twentieth century, and with it were connected the names of Einstein, Smoluchowski and Perrin.[9] The contributions of the first two were theoretical, while that of Perrin was largely experimental and furnished confirmation of the theories of the others.

One of the most remarkable observed facts in connection with the Brownian movement was that the rapidity of the agitation of a particle seemed to depend upon its size rather than its mass. Equally sized particles of metallic dust, droplets of oil and even air bubbles, in the opinion of good observers, showed very nearly the same agitation. It is likely that this observed fact, so contrary to what might be expected, had much to do with the slowness to accept the hypothesis of molecular collisions as the cause of the Brownian movement, for it is obvious that the impact of a bullet upon a cannon ball or a croquet ball should produce a greater velocity in the latter. But it is to be remembered that in the Brownian motion we observe not the consequences of individual impacts, but the resultant of many impacts. Einstein and Smoluchowski by independent paths arrived at formulas almost identical, which indicated that the resultant displacement of a very small suspended particle is independent of its mass, but varies inversely as its radius Moreover, their formulas, as well as that of Perrin, led to the conclusion that the ultimate distribution of the particles in an emulsion in equilibrium under the joint influence of gravity and molecular impacts should follow an exponential law similar to that of the density of the atmosphere as a function of the height.

Perrin saw in this an opportunity for a crucial experiment, and with consummate skill carried it through to a successful conclusion.

In addition, the formulas of Einstein and Smoluchowski involved Avogadro's constant, the number of molecules in a gram-molecule, as a function of quantities measurable in a given emulsion, such as the density of the liquid and that of the suspended particles, the radius of these particles and the exponential constant of vertical distribution Perrin's experiments gave a value for Avogadro's constant in good agreement with that given by other well-known methods, none of which involve the suppositions of the Brownian movement.

Largely as a result of Perrin's experimental work it has become clear to us that a suspended particle showing the Brownian motion is to be regarded simply as a big molecule. Below such particles we have colloidal suspensions, from which it is an easy step to such immense but undoubted molecules as those of Congo red, with a molecular weight of several hundred. Between a molecule and a particle there is no point where we can draw a sharp line of distinction. The kinetic theory of gases can be extended, as Van't Hoff showed, to the molecules of dilute solutions, and, as Perrin showed, to dilute emulsions.

Taking a broad view of the subject, Perrin saw that instead of accounting for the Brownian movement as a consequence of an assumed molecular structure of the suspending liquid, one might logically deduce the existence of molecules from the observed phenomenon of the Brownian motion. Perrin[10] pointed out that what is really strange and new in the Brownian movement is that it never stops, which at first seems in contradiction to our everyday experience of friction. If, for example, we pour a bucket of water into a tub, in a short

[9] Einstein, *Ann. der Physik*, 1905, p. 549 and 1906, p. 371; Smoluchowski, *Bull. de L'Acad. des Sciences de Cracovie*, July, 1906; *Ann. der Physik*, 21: p. 756, 1906; Perrin, *Annales de Chimie et de Physique*, September, 1909. Translated by Soddy, London, 1910, Taylor and Francis. (An excellent summary of the whole subject.)

[10] *Ibid.*

time the motion possessed by the liquid mass apparently disappears. As a matter of fact, what disappears is the coordination of the movement of the different parts of the water. The velocities at different points, at first almost equal and parallel as the water left the bucket, become more and more random and chaotic, distributing themselves in a fashion the more irregular the smaller the parts which we consider.

Perrin pointed out that this de-coordination does not proceed indefinitely. On the scale of microscopic observation, at the level of the Brownian motion, a re-coordination begins to be evident. If, at any instant, certain of the suspended particles stop moving, there are, at the same instant, in other regions particles which change from rest to motion. Since, therefore, the distribution of motion in a fluid does not progress indefinitely, but is limited by a spontaneous re-coordination, it follows that the fluids are themselves composed of granules or molecules which can assume all possible motions relative to one another, but which constitute a barrier to the further subdivision of the motion. If such molecules had no existence it is not apparent how there could be any limit to the de-coordination of motion.

Whether atoms might again be subdivided was generally regarded during most of the nineteenth century as rather an academic question. Physical changes, such as water to steam, could be explained without going below the molecule, chemical changes without going farther than the atom. But toward the end of the nineteenth century there were discovered new phenomena which not only furnished a fourth line of evidence for the reality of atoms, but opened our eyes to the existence of subatomic particles. This line of evidence arose from the study of the electric discharge through gases and from the discovery of radioactive substances.

In the early 1870's the chemist William Crookes was making weighings with a vacuum balance, and found some unaccountable disturbances, arising apparently from one pan of the balance being a little warmer than the other, as might occur by one side of the balance being warmed by sunlight. It was natural to account for these irregularities by convection currents, and the remedy was obvious: one must have a better vacuum. About this time the mercury air pump had undergone some improvements, and Crookes, becoming interested, added some refinements of his own which enabled him to attain a vacuum of better than a millionth of an atmosphere. Strangely enough, he found at this high exhaustion that the disturbing effect of light increased, and he was led to the construction of his radiometer. In such a vacuum the mean free path of a molecule of residual air becomes a matter of centimeters, comparable with the dimensions of the vacuum tube, and in such tubes Crookes discovered some novel and beautiful electrical effects which he exhibited at the meeting of the British Association at Sheffield in 1879.

Crookes showed that there was in such a tube a steady stream of electrified particles shot out from the cathode. He unquestioningly supposed these to be molecules of the residual air. He showed that this stream of particles could be deflected by a magnet, but did not follow up this point mathematically. This was perhaps natural, for at that time Maxwell's electromagnetic theory was still struggling for recognition. Moreover, Crookes was a chemist and not a mathematical physicist. It remained therefore for later workers (J. J. Thomson, Townsend, Wilson) to show that the negatively charged particles in a Crookes tube were not molecules or even atoms, but bodies of a minuteness hitherto unknown, being about 1/1,800 of the mass of a hydrogen atom. For these tiny bodies a new name was needed, and they were called "electrons" (electro-ions), the term "ion" having been for some time in use in electrolytic phenomena.

In the experiments of Thomson and others which made us acquainted with the properties of the electron the experimenters had to deal with these particles in large numbers, and the question naturally arose whether the results might not represent merely an average of a perhaps widely varying quantity This question was answered by Millikan in 1909, when by a very ingenious method he succeeded in isolating individual electrons and measuring their charges. These he found to be always the same from whatever material the electrons were derived

The possibility of the existence of particles still lighter than the electron has not been overlooked. Several observers, the most prominent of whom was Ehrenhaft, claimed to have found experimental evidence of such particles. Millikan, however, after an exhaustive discussion of the subject, is of the opinion that the evidence for a sub-electron is unsatisfactory

Just why, in the Crookes tube, a similar stream of positively charged particles was not emitted from the anode was a question not raised by Crookes Some years later, in 1886, such particles were found by Goldstein, who called them "canal rays," from the shape of his apparatus It was again some years before their nature was ascertained. Upon the discovery of radioactive bodies by Becquerel in 1896 it was found that these bodies emitted positively charged particles in abundance as well as negatively charged electrons. Eventually it was found that these positively charged particles were of two kinds, both much heavier than the electron. One kind of positive particles, called an alpha-particle, was found to have the mass of a helium atom (atomic mass 4), and the other kind called a proton, to correspond to a hydrogen atom (atomic mass 1). Both the alpha-particle and the proton, however, carry an electric charge equal and opposite to that of the electron. It was but natural to suppose that the alpha-particle was not an elementary unit, but was made up of four protons. Protons and electrons, therefore, came to be regarded as the ultimate building blocks of nature.

Much in the same way that the Brownian motion enables us to see the effect of the impacts of the invisible molecules there is a way in which we can see the impacts of the heavy and energetic alpha-particles emitted by radium. Take a watch or clock with luminous radium paint on its dial into a dark closet and examine it with a good magnifying glass; a jeweler's eyeglass will serve well The glow, which, to the unaided eye, appears uniform and steady, can be seen under the glass to be made up of myriads of tiny sparks, flashing up and dying down continually

Take a piece of lump sugar into the dark closet and break it by pressing on it with a knife blade. A flash of bluish light can be seen for an instant along the edge of the knife as the sugar breaks Light developed by the fracture of crystals is a well-known phenomenon, called "tribo-luminescence" It is quite different in nature from the spark produced when flint and steel are struck together. It is probably tribo-luminescence on a small scale which produces the glow of radium paint This paint is composed usually of a special form of zinc sulfide mixed with a trace of a radium compound The alpha-particles emitted by the radium strike the submicroscopic crystals of zinc sulfide and each tiny fracture generates a flash of light.

The great disproportion (about 1,800 to 1) in the relative masses of the negative electron and the positive proton has not failed to attract attention. Dirac speculated on the possible existence of what he called an anti-electron, of a mass equal to that of the electron, but carrying a positive charge. Some of his conclusions were so strange that it was difficult for many physicists to take his ideas seriously. For one thing, it ap-

peared, according to Dirac, that this anti-electron would of necessity be a very short-lived affair. Collision with a negative electron, or indeed with an atom or a molecule would, as Dirac thought, terminate the independent existence of the anti-electron, and in its stead would appear a little group of light waves, called a photon.

But in 1932 positively charged particles of very much this nature were discovered, of mass substantially the same as that of the electron. Recent experiment has shown that these particles, which have been called positrons, are in all probability as short lived as Dirac's anti-electron, and that after their brief existence is terminated by a fatal collision, they are reincarnated as light.

A negative electron, on the other hand, seems to be eternal. It may collide with atoms or molecules and rebound, suffering no change except in direction and speed. The reason for this fundamental difference in stability between the ultimate and positive particles is as yet not clear.

As long ago as 1920 Rutherford had directed attention to the theoretical possibility (perhaps even the probability) of the existence of an electrically neutral particle corresponding to the proton. In the same year in which the positron was discovered such a neutral particle was found by Chadwick. Whether this particle (called a neutron) is a close combination of a positive proton with a negative electron or whether it is an independent entity is not known.

We may summarize our present knowledge of nature's ultimate particles as given in the accompanying table.

It is not impossible that the vacant spaces in this table will at some time be filled, as has already been the case with the periodic table of the elements.

The philosopher is interested to observe that this fourth line of evidence for the existence of atoms, perhaps the most convincing of all, actually suggests in one of its aspects a compromise on equal terms between the discontinuous and continuous theories of matter. This aspect is that which is known as wave mechanics.

	Heavy particles (mass equal to hydrogen atom)	Light particles mass 1/1,800 of a hydrogen atom)
Positive charge	*Proton*	*Positron*
Negative charge	*(Unknown)*	*Electron*
Neutral	*Neutron*	*(Unknown)*

The electron in some of its activities acts like a particle; in some other respects it behaves as though it were a little group of waves, and the evidence in one case is just as good as in the other. Wave mechanics suggests a compromise to meet this difficulty.

The atom, according to Schrodinger, may be regarded as a group of waves (never mind of what) constituting a localization of energy at a certain point in space. Schrödinger's equations show that the amplitude of this group of waves falls off rapidly with the distance from the center of the group, so that the boundary of the atom, while strictly speaking vague, is for all practical purposes fairly definite. But, again strictly speaking, this amplitude falls off asymptotically to infinity, and in consequence two Schrödinger atoms, however far apart, are connected by an infinitesimally tenuous bond of the same nature as their own substance.

This modern adaptation of an ancient idea, this bridging of the centuries, calls to mind the well-known quatrain of Omar:

Myself when young did eagerly frequent
Doctor and Saint, and heard great argument
About it and about; but evermore
Came out by the same door where in I went.

THE LANGUAGE OF TREE RINGS

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THE idea of studying tree rings was conceived by Dr. A. E. Douglass, of the University of Arizona, in 1901 while on a buckboard trip through the great pine forest of northern Arizona. His interest in solar changes, especially the sun-spot cycle, led him to wonder if by chance that cycle might in some way influence the amount trees grow during a year. If such should be the case, the record of sun-spots by one stroke would be pushed several centuries back of any records kept by man. It might be, of course, that the sun does not act directly on the trees but acts through an agent, such as some phase of climate. If so, climatic records would also be greatly extended. Thus he reasoned, and the trees themselves in the years that followed have testified to the correctness of the reasoning.

How to Read Tree Rings

If one carefully examines sections of trees which lived together as neighbors he will notice that the rings are not all of the same size but that in many cases they vary a great deal in width from narrow to average and up to big. A passing acquaintanceship will reveal this variation in width Permanent friendship, however, will establish such familiarity with the individual rings of a single specimen that the identical rings can be recognized in an adjacent tree. Therein lies not only the thrill of discovery but also one of the secrets of reading tree rings.

Evergreen trees, such as pine, fir, and piñon, are more easily studied perhaps than others. With the coming of spring the tree awakens rather suddenly from its winter sleep. Growth is rapid at first and the wood formed is light-colored and porous. As summer advances, growth gradually slackens. The light-colored wood merges into a band which is darker and denser. When winter shuts down, the tree "closes shop," so to speak, and all growth ceases so abruptly that a sharp line marks the outside boundary of the wood put down during the spring and summer. Therefore, an annual ring consists of the light-colored wood, or spring growth, plus the dark-colored wood, or summer growth, and it is marked off by a sharp line at its beginning and one at its end. We are often led to say, for the sake of brevity, that an annual ring extends from the sharp outside of last year's ring to the sharp outside of this year's ring. Since we know such to be a fact, the art of ring reading lies in the acquisition of great familiarity with the variable sizes of rings and the invention of some scheme whereby the characteristics we come to recognize may be set permanently and usefully on paper.

Let us then return our thoughts to the subject of ring variations. If we obtain a collection of a dozen or so specimens from a certain locality and at leisure familiarize ourselves with the rings we will very soon notice that each ring possesses a surprising amount of individuality, so much so in fact that a very narrow ring on one specimen can be recognized in counterpart on most of the others. It does not take long until here and there on different specimens we can pick out rings very closely alike. The feeling comes to us that we are following something which repeats itself in

the different trees, something which is telling the same story over and over. Now, if we count out from a narrow ring we will find, say, the sixth ring very narrow, and the tenth and twelfth. These telltale rings, spaced at constant intervals on all specimens, establish with certainty the close relationship among the trees and the similarity of their records.

Ring sequences quite commonly possess outstanding configurations which serve as "finger prints" of identification in every sense of the words One series of rings we have at hand reads in part as follows. ring No. 3 small, 4 and 5 about average; 6 rather small, 7 small; 8 to 11 average; 12 small, 13 average; 14 to 16 big; 17 average; 18 rather small, 19 to 21 about average, 22 rather small, 23 and 24 about average; and 25 and 26 very small Another series gave the identical intervals as listed save that each number was greater by 20, thus 23 small; 24 and 25 about average; 26 rather small; 27 small, and so on Such configurations are just as striking, just as characteristic and just as symbolic of tree identity as is the pen and ink signature of personal identity. A wood section showing a signature reveals its intimate secrets as surely as a museum specimen with a glaring label.

The comparison, *i.e*, cross-dating, of our group of trees can be verified by paying attention to the dates on which the rings were grown. Suppose the trees were felled in the late autumn of 1920. All outside rings were formed during 1920 and represent that year. We count inward and place a single pin prick on 1910, three on 1900 for the century mark, one on 1890 and so on, and two on 1850 Narrow and big rings and the intervals between them can now be directly compared by the dates. We notice in particular the rings for 1913, 1904, 1902, 1900, 1880 and 1864, for example; they are small in all the trees. It should be pointed out hastily that we judge a ring to be small in relation to its near neighbors only, especially the two or three immediately preceding, and not upon what we might decide beforehand should be a typical size Since ring widths are judged relative to each other, even a group of small rings will generally possess a few rings narrower than the rest. It is this possession of very small and very large rings spaced at constant intervals and existing consistently over a homogeneous area of country which makes it possible not only to cross-date from tree to tree with certainty but also to plot a curve of the ring widths in order to show the varying success of the tree in its environment

So far the reading of tree rings appears to be quite a prosaic task but when apparently we are forced to crowd eleven rings into, or stretch nine rings out over, a ten-year interval, then tree rings become fascinating and challenge us to read the story they have to tell. Eleven annual rings in ten years is so obviously impossible that somewhere there must be a false ring which at first sight has the appearance of an annual. It is well at this point to recall two facts. (1) the annual ring extends from the sharp outside of last year's ring to the sharp outside of this year's ring, and (2) the annual ring itself consists of light-colored spring growth plus dark-colored summer growth, the light merging forward gradually into the dark, and not the reverse. Now, if we examine the ten-year interval closely we shall probably find somewhere a band of dark wood which fades into the light wood on both sides, indicating that the tree began to form typical late growth material rather too early in the season and had to return to early growth for a time before the actual growing season ended We call such a ring a double

because of the two dark bands, one of which fades on both sides and the other of which fades on the inside and ends in a sharp line on the outside (Fig. 1). The double, or "false ring," usually lies just inside the band of true late growth.

Occasionally a thin line of summer wood lies in the middle of what otherwise would be a single annual ring Is it a so-called "mid-line" or is it the outside of a separate annual? The entire circumference of the tree may have to be examined in order to reach a decision. If the line moves over so as to unite with an adjoining dark band, then it is not a mid-line, but part of a separate annual ring If the line does not move over, but ends "in the air," it is a true mid-line Another method remains, should the above one fail to yield a decision All the specimens of the collection covering the same time interval must be examined. If some of the specimens lack the line under question at the appropriate place, then it is very probably a mid-line.

The presence of nine rings to cover a ten-year interval does not seem so obviously impossible since one may have been lost. Of course, it was never lost—the tree simply did not grow a ring for a certain year on that part of the trunk because of adverse living conditions. The name "missing" has been applied to such rings, and it is a good one It may be imagined what difficulties arose because of missing rings during the inception of tree-ring study. Before he had discovered that rings could be missing, Dr. Douglass made the following note (February 15, 1904): "I find small rings not to be depended upon. . . ." Either the intervals between two small rings did not remain constant on different specimens, or sometimes a ring was small and another time it was not. In both cases missing rings were to blame The small ring on one specimen was absent on the other—simple when discovered but no end of trouble previously.

Diagrams (Fig. 2) perhaps will help us quickly to an understanding of missing rings Diagram a shows ring No. 3 of average size. In b it is very small, and sometimes so much so that it is microscopic. In c and d ring No 3 is locally absent (lo ab., for short) over a part of the circumference, and in e it is entirely absent, or missing We can see at once that the existence of ring No. 3 in c and d can be established by close inspection of the entire circumference. Constant carefulness will prevent our overlooking rings locally absent. The case of diagram e is different. Here cross-dating with other specimens covering the same time interval not only reveals the lack of one ring for the interval but indicates exactly where the missing ring should be supplied as well The thorough check provided by cross-dating in the revelation of doubles, mid-lines

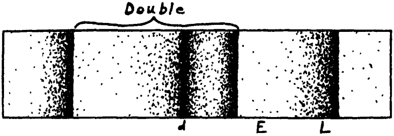

FIG. 1 THE DOUBLE OR "FALSE" RING.

THE BAND OF DARK-COLORED WOOD LABELLED "D" WAS FORMED DURING THE GROWING SEASON AND NOT AT ITS END. E = EARLY GROWTH OR SPRING WOOD FOR THAT PARTICULAR RING AND L = LATE GROWTH OR SUMMER WOOD.

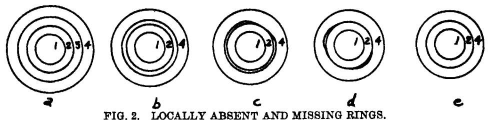

FIG. 2. LOCALLY ABSENT AND MISSING RINGS.
RING No. 3 IS OF AVERAGE SIZE AT THE LEFT AND IS MISSING AT THE RIGHT.

and locally absent and missing rings makes the process one of fundamental importance to the field of tree-ring research.

It may be of interest to quote a passage from the notes of Dr. Douglass giving the first hints of cross-dating in the dawning realization that rings on opposite sides of a tree were identical. "Tried opposite sides and find that rings on opposite sides readily identify. Identified the 1801 ring and others about 1750 and 1850 without knowing their precise place and then counted and found them correctly placed with reference to each other." The note was written on February 15, 1904 But not until 1911 was the full importance of cross-dating realized. It was the most significant step in all tree-ring studies; it gave the needed accuracy to ring identification and a solid foundation from which to read the story of tree rings.

A knowledge of how to "read" tree rings and how to cross-date specimens will permit us to understand the construction of a tree-ring calendar, or a so-called master chart for a given region if we can devise some graphic method to represent the individual rings To make such a calendar possible the region must possess living trees as well as material from forests which lived before the present one. A wide choice of specimens properly selected so that they dovetail together is a necessary requirement for a well-balanced, thoroughly verified calendar. Fig. 3 shows how the chain of specimens wrought out of strong links safely articulated reaches unbroken

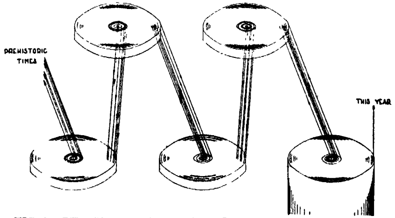

FIG. 3. THE CONSTRUCTION OF THE TREE-RING CALENDAR.
THE YOUNGEST SPECIMEN AT THE INSIDE MATCHES THE OUTSIDE OF THE NEXT OLDER, THE INSIDE OF THIS ONE MATCHES THE OUTSIDE OF THE SECOND OLDER, AND SO ON INTO PREHISTORIC TIMES. EACH SPECIMEN BRIDGES THE GAP FROM THE PREVIOUS RECORD TO THE ONE FOLLOWING.

from the youngest ring at the right to the oldest at the left. The diagram is schematic and ideal. Nevertheless, it illustrates two things: first, that the inside of the youngest tree matches the outside of the next older and, second, that each specimen not only matches the previous one but also extends it backward in time. Thus a tree-ring calendar is built up with every ring definitely dated at a particular year if each part of the entire sequence has been verified and duplicated as much as abundance of material permits or until uncertainty no longer exists The process whereby a ring record is extended either forward or backward in time is known as chronology building. It is accomplished by means of identifying like rings and like intervals on different specimens, as was previously explained, or in other words, by means of cross-dating

A tree-ring calendar gives us a standard sequence of rings and represents our greatest desire for any region. In fact, the working out of a standard sequence is the initial and all-important task in tree-ring study. That done, other problems dependent upon the standard can be approached with definite hope of solution. Let us suppose, for instance, that we come into possession of a mass of material wholly unfamiliar to us. The first specimen selected shows certain noteworthy rings and certain intervals which can be recognized on a second, a third and many others. Since it is not practical to remember all the separate sequences we are justified in placing the specimens side by side, selecting those characteristic rings common to the entire lot, and holding them in mind as a standard sequence representative of the collection. True calendar dates not being known as yet, an arbitrary zero may be assigned to some one ring and the others numbered accordingly. Such a sequence is then known as a relatively dated standard, or briefly, an R.D.S.

Now an R.D.S. may occupy one of three positions in relation to the real standard sequence; that is, it may precede, follow or match part of the standard. If it matches, actual dates may at once be assigned and the problem is solved. If the R.D.S. does not match, patience must be exercised until the record has been extended far enough by means of the process of chronology building so that in the extended form it joins firmly and surely onto the dated standard. Gaps between an undated sequence and the tree-ring calendar have been bridged from time to time in the past. The most famous of the gaps, just prior to 1300 A. D., was closed by material collected by the National Geographic Society Expedition of 1929.

A little consideration will reveal the potent nature of the scheme involved in setting up an R.D.S., for it helps directly in the solution of all major problems concerned with chronology building and helps in the dating of masses of new material. In actual practise in our tree-ring laboratory the R.D.S. system is of invaluable assistance and is used constantly. Several such relatively dated standards are in existence at the present time. Should a new region fail to yield a dated standard at first, recourse must be had in an R.D S. Relative dating has had great value in the study of collections from the ancient ruins of Indian pueblos in the Southwest and could be used in similar fashion with ancient material from other parts of the earth.

Down to here we have assumed that all ring features are held in the memory. Truth to say, the memory method of ring reading has enormous value because of its great facility and ease of application under all conditions and because the wood upon which memory is based possesses all the features characteristic of a given sequence, something no secondary method of ring representation could

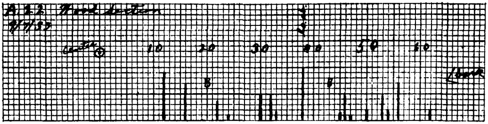

FIG. 4. THE SKELETON PLOT

THE YEARS, AND THEREFORE THE ANNUAL RINGS, ARE NUMBERED FROM LEFT TO RIGHT ON THE PRINTED LINES. EACH LINE REPRESENTING A NARROW RING IS INKED TO A LENGTH WHICH IS INDICATIVE OF THE NARROWNESS IN THE SENSE THAT THE NARROWER RINGS ARE MARKED BY LONGER LINES. "B" STANDS FOR "BIG," AND "LO AB" FOR LOCALLY ABSENT.

show. The memory method, however, becomes impractical if not impossible, as sequences accumulate in number Hence it becomes necessary to devise a means of placing the diagnostic features which reveal the essential characteristics of a specimen upon paper for permanent use.

Let us take an undated specimen as an example. We count out from the center, placing a pin prick in the tenth ring, the twentieth, thirtieth, and so on. In that way each ring has a specific number. A sheet of paper is prepared by placing the number of the specimen, the date and the type of wood at the top. Then we "read" the rings. The numbers of all rings having diagnostic features are placed in a column so that telltale rings and the intervals between them are recorded Suppose ring No. 12 is extremely small: we underline the written figure 12 three or four times. Suppose ring No. 16 is very small: we give it two or three lines. Ring No. 22 is rather small · we give it one line. Ring No. 24 is just noticeably small · it received no line. If ring No. 20 is unusually big we note the fact on the paper so: (20 B). It must not be forgotten that, throughout the whole process of reading, rings are judged small or big in comparison with their immediate neighbors only. The sheet of paper when completed contains the so-called number plot and gives a record which is permanent for our files but which is very cumbersome to use as a record by itself.

In order to make the number plot useful in a practical and rapid way it is changed into a skeleton plot. Coordinate paper, with centimeters marked by heavy lines and with the small divisions two millimeters square, is cut lengthwise into strips four and a half centimeters wide. If one strip is not long enough two or more may be glued together, care being taken that the divisions match accurately Each vertical two-millimeter line represents an annual ring and the lines are numbered from left to right Ring No. 12 was taken to be extremely small; a long ink line is therefore drawn at the appropriate place on the coordinate paper Ring No. 16 receives a somewhat shorter line than No 12, No 22 still shorter and No 24 just a touch (Fig. 4). The completed skeleton plot gives us something very convenient to use, since it is easily carried about and since it can be readily placed on top of another one to see if the inked lines match, that is, cross-date.

A further word may well be given on the individual skeleton plot. If too many lines are drawn the plot becomes

meaningless. Only those rings which are conspicuous, telltale and diagnostic should be represented for the same reason that in our daily lives we are more apt to remember and compare people and places because of certain outstanding characteristics rather than because of trifling details.

Let us carry our knowledge of skeleton plots back to the collection of specimens considered previously and construct plots for all individuals It is commonly more convenient to cross-date skeleton plots than it is to compare pieces of wood. Then, too, plots may be carried about and matched at odd moments. If plots which cross-date are placed side by side in correct position year for year the lines common to the group may be copied down on a separate strip of coordinate paper (Fig 5). Such a procedure merges the features common to all the individuals into a single plot, the so-called standard or master chart. Chronologies either relative or absolute are built up in this way and in actual practise the tree-ring calendar in the form of a master chart is used for dating and correlation purposes. The master chart for the Central Pueblo Area of Arizona and New Mexico built up by Dr. Douglass by the method of chronology building illustrated in Fig 3 now reaches back more than a thousand years. It was made from living trees and from beams incorporated in the pueblos by the Indians of early historic and prehistoric times. For each of a thousand years we have a separate ring, a telltale witness to all the vicissitudes of environment, however good or bad, for tree-growth The rings picture the life histories of the trees, the struggle against famine and the luxuriance of plenty. Each factor influencing the well-being of the tree, whether it be the soil of the earth or the rays of the sun, the snows of winter or the drought of

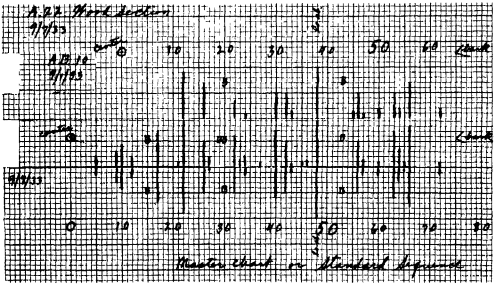

FIG. 5. THE CROSS-DATING OF SKELETON PLOTS AND THE CONSTRUCTION OF A MASTER CHART.

THE NUMBERS ON THE MASTER CHART ARE FOR ILLUSTRATIVE PURPOSES ONLY. THE PLOT LABELED MASTER CHART IS ACTUALLY A RELATIVELY DATED STANDARD IN THIS CASE.

summer, leaves its impress somewhere in the body of the tree. If we have the eyes to read we may glean bits of the fascinating story not only for the year just gone but also for a thousand years ago, and even a million years or more back in the history of plant life.

WHAT TREE RINGS TELL

Reading of tree rings and the building of chronologies are intriguing puzzles, ever leading the reader onward from one solution to another without end. The work may be difficult, painstaking and laborious as a rule; yet it comes to be viewed in the light of a genuine pleasure, time-consuming and compelling. Nevertheless, ring reading is but half the story. The application of the knowledge gained and the story written in the rings are after all the things we want to do and know. We must learn to read and understand.

The master chart, it will be remembered, shows the nature of the rings for all the years throughout its course. Suppose some one sends us from the region of the master chart a specimen which he wants dated. We examine it, and perhaps the narrow rings and intervals between them will reveal the dates. If memory fails, we construct a skeleton plot that is moved slowly along the master chart until a fit is obtained. Thus, the specimen is dated and the outside ring gives the exact date when the tree was killed or cut down. The possibilities of dating become strikingly apparent on our learning that among the Indian ruins of the Southwest we can tell to the year in most cases when the timbers were cut for the original structure, for repairs or for reconstruction by later generations.

The Indian pueblos of the Southwest are simply one example. Consider the possibilities of the system in connection with the dating of prehistoric materials from other parts of the earth. What a revelation we may aspire to in the future! Many problems, legal, historic or scientific, may be capable of solution.

Now we must turn to the story that tree rings themselves have to tell. Fire, lightning, pest effects, wind, disease, frost—all these and others, highly interesting in themselves, leave their marks upon the growing tree, but the chief objective in tree-ring work lies along somewhat different lines. When we make a collection we desire normal, healthy trees, trees representative of the normal conditions of the environment under which they lived. A tree is more than an organism modified by its environment, it is a manifestation of that environment—a complex of cells born of and nourished in the natural products of a locality and shaped through life by the interaction of materials and forces amalgamated in the body of the tree. Each factor having an influence on the tree leaves its impress. It is a task for our eyes to learn to read the telltale signs and unravel the skein of evidence.

The personal life of a tree, whether in success or failure, in ease or adversity, is an illuminating subject for study, whether we know the exact name of the tree or not. The individual tree can not, of course, move about; it must take things as they come. When conditions are good and all factors work in harmony our trees are happy, prosperous and well fed; but when conditions are bad and certain factors become weak or antagonistic the trees are miserable, pauperized and undernourished. Tree-growth, in other words, more or less faithfully records living conditions in particular for a single locality or in general for an entire region. Since the general story should properly come first, we merge the records of a group of trees so that we may obtain an insight into

the conditions or factors affecting the forest as a whole. The following remarks are made from this larger regional view-point and, it is hoped, they will illustrate how bits of the story of the past are revealed by tree rings. For the past lives again in him who learns to read.

The mutual interaction of factors in near optimum amounts is necessary to the constant well-being of a tree. Any essential variation will leave a mark. In certain regions the fluctuations of some one factor are so important that it serves as the major control of tree-growth. Perhaps it is water supply, sunshine, temperature, behavior of the sun or others.

Let us consider the case in which water supply represented by rainfall is just enough on the average for the requirements of the trees. The average ring, then, will reflect the average rainfall. By the same token, the narrower the ring is the less the rainfall of the corresponding season, in general. A very narrow ring tells us that a tree is fighting for its existence. Times are hard, water and food are scarce, life is precarious, and a few weaker trees may die. A ring locally absent perhaps signifies that only a few of the roots were able to secure water and food: they were not sufficiently plentiful for the tree to form a complete ring. On the other hand, a large ring indicates more than average rainfall. We may well imagine the happiness and peace of mind of the tree, were it conscious, when it feels assured of plenty to eat and drink.

The double ring is of equal interest. Conditions become unfavorable in the late spring and the tree begins to "close shop," as it were, by forming some dark-colored summer wood. As the harsh conditions relax and the summer rains begin, the growth gradually returns to the spring type for a time prior to the real end of the growing season. Thus, doubles appear to tell us of a double season, that is, a year in which the late spring and early summer drought is so severe and so protracted that the precipitation of the previous winter can not last over the dry spell.

Once interested in life in relation to its surroundings we may begin to vision the breadth of the investigation. It is not a single highway but an intricate pattern of diverging roads, each one beckoning for exploration and promising the fruits thereof.

If we measure the rings of a sequence accurately in millimeters and construct a graph of the measures plotted year by year we obtain a wavy line, or "curve," composed of successive crests and troughs. The ring measures in such form are ready for an analysis, which consists of a study of the intervals between successive crests. Since the crests represent times when the trees grew rapidly and flourished, they speak to us of causes and associations which work intermittently to the benefit of the trees. Evidence has accumulated, for instance, showing that variations in tree-growth correspond to a certain extent to variations in the sun. The sun probably exerts much of its influence through the agency of rainfall on the earth. We see at once that astronomy and meteorology lend material assistance in the study of tree rings. But observations of the sun go back only to the early decades of the seventeenth century. Therefore the rings of the giant Sequoias extending backward several thousands of years have in their turn something of value to tell astronomers. Meteorology likewise receives a long record of weather conditions. Since a forest as a whole is subject to climatic variations, the science of climatology gives as well as receives information of importance.

Archeology happily furnishes us with a wealth of prehistoric material, which on being dated supplies archeologists with exact dates of pueblo occupation. Fossil trees are not at all uncommon down in the rocks of geologic time. With our knowledge of what tree rings tell we can not only trace a lightning scar that blasted its way down a tree trunk millions of years ago, but we can also read something of the weather and climate in the dim ages gone. Are those same rings trying to tell us something of the history of the sun? Botany is not the least of the fields of man's endeavor to have a vital influence on the study of tree rings. The two studies constantly must work hand in hand. Last of all, there is the science of ecology which is intensely interested in that most fascinating of all stories on the face of the earth, the relation of living things to their surroundings. Through the whole gamut of the sciences each has a necessary part, to give and to receive, in the ecological study of trees and the rings they create from year to year.

So we have a sort of mutual benefit association. A list of the members is rather impressive: astronomy, meteorology, climatology, archeology, geology, botany and ecology. It may not be long until chemistry and physics are invited to do their rightful share. When we consider leisurely that tree-growth not only reaches backward in time but also stretches through space to all parts of the earth we begin to see a vista of vast possibilities for the inquisitive human mind. Whole regions of knowledge await investigation. Fortunately a well-marked trail has been blazed into the unknown by the founder of tree-ring studies in whose mind the idea was originally conceived and painstakingly elaborated.

JENNY HANIVERS, DRAGONS AND BASILISKS IN THE OLD NATURAL HISTORY BOOKS AND IN MODERN TIMES

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A MODERN JENNY HANIVER

SOME years ago Mr. S. Altman of Brooklyn came to my office bringing the curious object shown in Fig. 1. I explained to him that this was a Jenny Haniver, made of a ray transformed by hand and dried into this mythological monster. He very kindly left it with me until I could have made the photograph reproduced as Fig. 1. This was filed away and, as it came to me, like material was added with a view to the article now presented.

The scanty history of this specimen is as follows. Years ago Mr. Altman's father purchased an old colonial house on Ocean Avenue, Brooklyn. The house had been long unoccupied when it was turned over to the wreckers in 1925. Among the old things rescued from it by Mr. Altman was this specimen, which he found hanging over a mantel in one of the rooms. Its source can not be traced further

The head-dress of this Jenny Haniver is made of the rostral cartilage, with the flexible membranes partly wrapped about it. The eyes are artificial ones inserted in the nostrils. The flat mouth has been pulled out to give the jaws somewhat the curvature of those in a primate. The tissues on either side of the mouth have been distended into bulging cheeks. The upper parts of the pectoral fins have been folded back behind the head, leaving the remainder of the fins to form the wings. The appendages of the pelvic fins of this male fish have been manipulated to form something like legs, and these are supported by wires run through the tissues. Part of the fin membrane is seen on the outside of each "leg." At the junction of fins and body are the conjoined enlarged bases of the fins with points extending upward and outward right and left somewhat resembling the pelvic arch of a primate—of which they are in a certain sense the antecedents.

Such, then, is a modern Jenny Haniver, made of a skate distorted by hand and dried in the form of this mythological monster It is to be regretted that the history of this specimen can not be traced further than the brief account already given.

THE ORIGIN OF THE NAME JENNY HANIVER

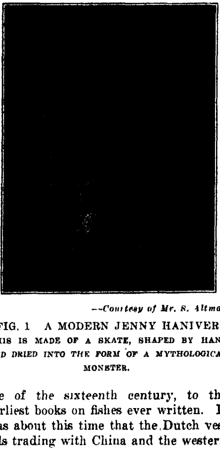
The appellation, Jenny Haniver, is as interesting as unusual. I have known of it for years but have no clear idea of its origin. The only other writer on these manipulated rays who uses this name is Mr. Gilbert P. Whitley of the Australian Museum, Sydney, whose article will be referred to later. We have both vainly sought to trace the origin of the term and have failed. The word is not even in the Oxford New English Dictionary, nor in any of the dialect dictionaries we have been able to examine. But Mr. Whitley got the following suggestion from Dr. Rivis Mead of Waitara, New South Wales, who had formerly owned a Jenny Haniver. Dr. Mead writes:

> The distorted small skate sent you was purchased in a shop in Whitby, Yorks, England,

where the saleswoman had a long story about their capture on the coasts of Belgium and Holland. The name as given to me sounded like Jeanie Hanvers, so maybe it has something to do with "Anvers," the French name for Antwerp—a probable place of their origin Possibly they are made there by fishermen or sailors.

The History of These Mythological Monsters Traced in Figures from Old Books

For the origin of these man-made monsters, we must go back to the middle of the sixteenth century, to the earliest books on fishes ever written. It was about this time that the Dutch vessels trading with China and the western islands of the Malay Archipelago brought back hand-made mermaids (half monkey and half fish). These and their manufacture had already been made known to Europeans by the great medieval traveler, Marco Polo (in Book III, chap. ix—vol. II, pp. 285–286 of the Yule-Cordier ed. of 1921). I strongly suspect that these "mermaids" were largely responsible for two remarkable "fishes," the "monkfish" and the "bishopfish," figured in the books of those early founders of ichthyology, Belon, Rondelet, Gesner and Aldrovandi. Perhaps reproductions of these figures and brief references to them may be of interest.



—*Courtesy of Mr. R. Altman*

FIG. 1 A MODERN JENNY HANIVER
THIS IS MADE OF A SKATE, SHAPED BY HAND AND DRIED INTO THE FORM OF A MYTHOLOGICAL MONSTER.

The earliest published figure of the monkfish is found in what is the first treatise on fishes in the history of the world, Pierre Belon's

De aquatilibus, Libri duo
Cum eiconibus ad vivam ipsorum effigiem
quod eius fieri potuit, expressis
Parisiis, MDLIII.

On page 39 is found the picture shown herein as Fig. 2. Of the origin of this "fish," Belon says that it was taken in Norway at Diezunt near the town of Den Elepoch and that it lived three days, giving out (not unwarrantedly) lamentations of distress.

Belon, in the French version of his book published at Paris in 1555, gives the same figure, which he says is that of "un homme marin." He then discusses sirens, tritons, naiads and mermaids; and gives several accounts of these later. Evidently he links his monkfish with the mermaid.

Guillaume Rondelet, a contemporary of Belon, in his book, "Libri de Piscibus Marinis," Lugduni [Lyons], 1554, has a better drawn figure of the monkfish, but one differing only in details from Belon's. However, his account of the fish is much fuller. After speaking of marine monsters, he adds that:

Among these let us place that which was in our time captured in Norway in a tempestuous sea. All who saw it at once gave it the name of monk, for it had the visage of a man, but one rustic and uncouth. Its head was shaven and smooth and a cloak like that of a monk covered its shoulders. Instead of arms, it had

two long fins, its lower part ended in a broad tail, and its middle part was broader and formed like a military cloak. The picture of this was given me by the illustrious Margaret, Queen of Navarre. . . . She had received this effigy from a nobleman, who had brought a similar one to the Emperor Charles the Fifth then passing through Spain This nobleman told the queen that he had seen this monster captured in Norway at Diezum near the town called Denelopoch after it had been thrown on shore by the huge waves of a great storm. Furthermore Gisbertus the physician showed me in Rome a picture of this same monster differing in no whit from mine.

However, Rondelet, who was regius professor of medicine in the celebrated medical school at Montpellier in southern France, did not swallow this monkfish whole, but like the scientific ichthyologist he was, added that "To set forth my own views, I think that certain details beyond the truth of the matter have

—*After Belon, 1553*

FIG 2. THE FISH IN THE DRESS OF A MONK

THE MONKFISH OR SEA MONK.

—*After Rondelet, 1554*

FIG. 3. THE FISH GARBED LIKE A BISHOP

THE SEA BISHOP OR BISHOPFISH

—*After Günther, 1880*

FIG. 4. LOWER ASPECT OF HEAD OF RAIA LEMPRIERI

NOTE THE RESEMBLANCE TO A HUMAN FACE.

—*After Belon, 1551*

FIG 5. AQUILA MARINA, THE SEA EAGLE

THE PROBABLE ANCESTOR OF THE JENNY HANIVERS.

been added by the painter to make the thing seem more marvellous." He then speaks of it as "homo maris," a merman, and relates a story of such in the Gulf of Cadiz His account and figure seem then to tie up definitely with the mermaid stories.

This drawing (there must have been a factory of them) is also found in various books. Thus Rondelet reproduced it in the French translation of his book published at "Lion," in 1558. So also did Conradus Lycosthenes in his "Prodigiorum ac Ostentorum Chronicum" (Basiliae, 1557), Gesner, Aldrovandi and others.

In his second book (1555) referred to above, Belon refers to a record in the annals of Brabant of a fish clothed like a bishop and having a pontifical miter on his head, but he gives no figure. In the whole matter he had been anticipated by one year by Rondelet. In this author's "Libri de Piscibus Marinis," Lugduni, 1554, we find the interesting picture reproduced herein as Fig. 3. This in many ways is more mermaid-like than is the monkfish. Its origin in Amsterdam favors the mermaid idea as does its disappearance in the sea on the Polish coast (?). Of it Rondelet writes:

> I set forth [the figure of] another monster much more marvellous, which I received from Gisbertus Germanus. This he had received from Amsterdam along with letters which affirmed that in 1531 a sea monster clothed like a bishop had been brought before the King of Poland. This had vehemently indicated by certain signs that it desired to be restored to the sea. Led thither it had thrown itself into this.

However, Rondelet was very skeptical, for he adds that:

> I have intentionally omitted many details which were told me about this monster, since I deem them fables. For it is the vanity of men, that about a thing marvellous enough in itself, they wish to add many things besides the truth.[1] I have received such a figure of this monster and reproduce it herein. Whether it is a true thing, I neither affirm nor deny.

These figures and descriptions were well known and often referred to. Thus Du Bartas in his "Divine Weekes & Workes," published in English at London in 1608, speaks of them thus:

> The mytred Bishop and the cowled Fryer;
> Whereof, examples (but a few years since)
> Were shew'n the Norways and Polonian Prince.

This is a weird-looking apparition (Fig. 3) with a very unbishop-like look

[1] How accurately this (1554) sums up the mental attitude of the average newspaper and magazine publicist of the present day (1934).

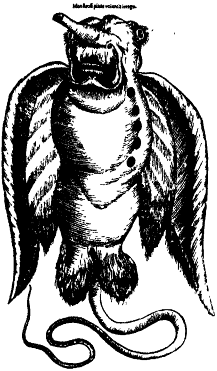
in the eye. The miter-like head-dress and the cloak do lend some credence to the name bishopfish. Furthermore, the underside of the head of some rays does offer some resemblance to that of a monstrous human face. This may be seen in Fig. 4, Günther's figure of the lower aspect of the head of a ray. Note particularly the swollen "cheeks," like those shown in Fig. 1. A fine Jenny Haniver could have been made from the ray whose face is thus portrayed.

The figure (Fig. 3) of Rondelet's' bishopfish, like that of Belon's monkfish (Fig. 2) was many times reproduced in the next 50 or 75 years. But it is now time to turn to that picture which I regard as the forerunner, if not the actual progenitor, of the race of Jenny Hanivers.

Reference has already been made to the "De Aquatilibus" of Pierre Belon, published at Paris in 1553. On page 97 of this work one finds the "effigy" of the European eagle ray, shown herein in Fig. 5. This seems to have been reproduced from a larger drawing, for behind and to the left of this ray are seen the hinder parts (including tail and sting) of another ray. It is a crude woodcut, which shows the open mouth, the two tooth-plates, the pendant upper lip with the paired nostrils looking like eyes, and the pointed snout distorted to stand nearly at right angles to the head, and above and back the upper head is twisted to show the left eye

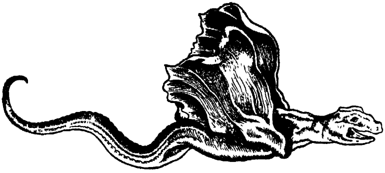
Whether or not this was intended for a Jenny Haniver can not be positively stated, but it has been distorted in the head region and it has a certain resemblance to such a mythical monster. I believe it to be the figure which serves as a starting point from which to trace the development of Jenny Hanivers, dragons and basilisks.

This figure was also much copied and somewhat changed. Where we last find it, in Ulysses Aldrovandi's "De Piscibus Libri V" (Bononiae 1613, p. 437), it has plainly been much "improved" and is well on its way toward becoming a Jenny Haniver, as may be seen in Fig. 6. Among the "improvements" are the omission of the spine on the tail and the presence of two wings on each side instead of one with a notch in it. The body has one backwardly pointed transverse corrugation instead of five gently curved ones, and there are five round apertures on either side to represent the paired gill-slits not visible in Rondelet's drawing. The head is most improved: the lower lip is accentuated and the median notch has been upturned; the flat grinding teeth are better drawn; the upper lip is hairy; the left nostril only is clearly drawn; the snout, standing at



—*After Aldrovandi, 1613*

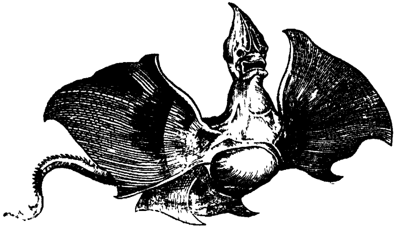
FIG. 6. IMAGE OF A MONSTER "AQUILA MARINA"
A LATER AND "IMPROVED" SEA-EAGLE.



—After Gesner, 1558

FIG. 7. A FLYING DRAGON MADE OF A RAY

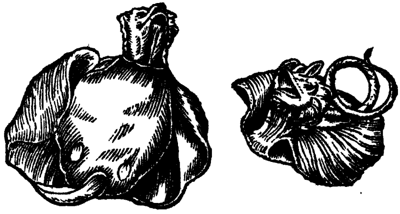
THE FINS HAVE BEEN TRIMMED AND BENT UPWARD TO FORM WINGS.



—After Aldrovandi, 1613

FIG 8. "RAIA EXICCATA & CONCINNATA AD FORMAM DRACONIS"

ANOTHER FLYING DRAGON—WITH A MITERED HEAD.



—After Aldrovandi, 1640

FIG. 9. "BASILISCUS EX RAIA EFFICTUS PRONI & SUPINE PICTUS"

THE FABLED BASILISK SHOWN IN TWO POSITIONS.

a right angle to the head, is longer and is truncate at the tip; and finally both eyes are now visible, are supplied with eyebrows and are very staring.

Belon does not allege that his ray is a monster, but Aldrovandi does, as is indicated by the legend above its head in his figure. Belon's specimen presumably came from the Gulf of Lyons, but he states that it is found in the Adriatic Sea as well. In fact it is common in the western Mediterranean. Aldrovandi got his description of this monster from the section on monsters in the 1579 edition of the works of the great French surgeon, Ambroise Paré. Paré describes it as a fish about four feet wide and terrible and marvelous to see, having a great head, two sets of eyes, two great ears (the spiracles?), a very fleshy snout green in color, wings double, five openings on each side of the body and a long tail. Aldrovandi's drawing (Fig. 6 herein) fits the description, but seems to me to have surely been based on Belon's representation (see Fig. 5).

The Swiss zoological encyclopedist, Conrad Gesner, published his great "Historia Animalium," at Tiguri (Zurich), 1551–1587, in 5 thick folio volumes. Part four of this, entitled "De Piscium & Aquatilium Animantium Natura . . . cum Iconibus," etc., was published in 1558. On page 945 is found the figure copied as Fig. 7 herein. Gesner gives no name for this, which, however, may well be called the flying dragon. It is the first definite illustration of a Jenny Haniver known to me. This is found in "Lib. IIII" at the end of the section "De Raijs." Here follows a translation of Gesner's Latin:

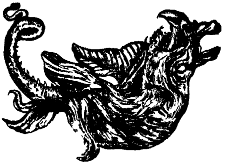
> The vendors of [quack] medicines and certain others [of that ilk] are accustomed to dry rays and fashion their skeletons into varied and wonderful shapes for [exhibition to] the multitude. They also exhibit others which resemble the serpent or the winged dragon. [To make these] they bend the body [of a ray], distort the head and mouth, and cut away other parts. They take away the forward parts of the sides [the fins or wings] and raise up the remainders that they may simulate wings, and other parts they modify as they wish. I depict here [Fig. 7 herein] such a specimen as was once brought to me.

Gesner did not know the kind of ray used to produce the winged dragon portrayed in Fig. 7, but he had a very clear understanding of how it was manufactured (literally, "made by hand")—and this in the year 1558.

For our next Jenny Haniver (and the most artistic of all the old ones) we must go to Ulyssis Aldrovandi's "De Piscibus," Bononiae (Bologna) 1613, p. 443. Here we have what our old Italian encyclopedist calls the dragonfish because of its wings, but which I would also like to call the bishopfish because of the way that the snout has been manipulated to form a miter-like headpiece. It might also be called a basilisk, since it is the progenitor of a long succession of such mythical monsters—some of which will be shown further on in this article.

This Jenny Haniver, shown in Fig. 8, should be compared with the modern one portrayed in Fig. 1. Here (Fig. 8) the wings (pectoral fins) have been trimmed or manipulated to separate them from the head by smooth curves. The pelvic fins are pulled downward and probably drawn somewhat enlarged. The mouth has been widely distorted, the nostrils have been drawn to represent eyes, and the snout has been molded to simulate a bishop's miter. This Jenny Haniver is much more artistic than the one photographed in Fig. 1.

On his very next page (444) Aldrovandi has portrayed a rather crude dragon hand-fabricated from another ray. This, seen in Fig. 10, has a mouth pulled out in elongate fashion and widely opened, showing the teeth; both eyes (nostrils) are visible, thanks to bad drawing; and the snout is bent abruptly backward. The anterior fins have been manipulated to form wings, and the



—After Aldrovandi, 1613

FIG. 10. "DRACO EFFICTUS EX RAIA"
ANOTHER DRAGON MADE FROM A DRIED RAY.

—After Lochner von Hummelstein, 1716

FIG. 11. AN "OVER"-FABRICATED DRAGON OR BASILISK
THIS HAS FOUR FEET IN ADDITION TO WINGS.

hinder ones to (faintly) simulate feet, while the tail is twisted into a corkscrew.

Of these two mythological monsters, Aldrovandi gives no particular data, merely saying that "Showmen fashion diverse-shaped figures from dried rays and foist these on the ignorant either for dragons or for basilisks. I am pleased to show here two of these."

In 1640, there was posthumously published at Bologna, in folio form, Aldrovandi's "Serpentum et Draconum." Liber II of this is devoted to dragons, and at the beginning are reproduced the two figures shown herein as Figs. 8 and 10. The statements concerning them are essentially those given above. Then on p. 364, Aldrovandi figures in two positions the basilisk shown in Fig. 9. His brief statement is that this specimen, fashioned of a dried ray, was seen by the renowned Mercurialis in the treasure house (museum?) of the Emperor Maximilian. In these figures is portrayed the most contorted and crudely drawn specimen found in the old books.

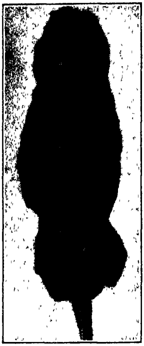
The next of these artificial monsters discovered in this search is the remarkable object portrayed in Fig. 11. This was found among the curiosities collected by B. and M. R. Besler and figured by J. H. Lochner in "Rariora Musei Besleriani," Norimbergae, 1716. Lochner calls it a basilisk or a dragon, but distinctly says that it is an artificially distorted dried ray.

It is indeed an extraordinary object, comparable to Aldrovandi's dragon shown in Fig. 10. Whether the object was better finished than the other, the drawing was certainly better, as may be seen in Fig. 11. Like the former, the head parts have been much distorted and the snout forms a miter-like projecting horn; but the pectoral fins have been separated from the head and split to form anterior foot-like organs and posterior wings. The fish must have been a male, for the hind limbs seem to have been made of the claspers.

Basilic.

—After Duhamel du Monceau, 1777

FIG. 12. A MORE MODERN BASILISK
THIS ONE IS PROVIDED WITH PAWS AS WELL AS WINGS.



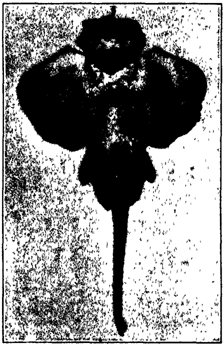
—*From a photograph by courtesy of Mr. G P Whitley*

FIG. 13 AN ENGLISH JENNY HANIVER

THIS IS PROBABLY NOT OVER FIFTY YEARS OLD.

Another and a very artistic basilisk is that shown in Fig. 12. It was found in Duhamel du Monceau's "Traité Générale des Pesches" (vol. III, Sec. IX, pl. vii, fig. 2), Paris, 1777. This is fashioned very much after the pattern of Aldrovandi's "dragon" of 1613 (Fig. 10), but with certain "improvements." Instead of outspread pectoral fins this "basilic" has lion-like fore-paws set at the anterior base of the pectoral fins, the mouth is much enlarged, behind the eye is a horn, the snout is twisted forward and downward into a French "liberty cap," and the wings are stayed-out by six boomlike rays. These paws are probably artificially made of some foreign material and sewed or cemented on to the body in the region where the anterior part of the pectorals has been cut away. Although but one "basilic" is figured, Duhamel states that he possessed several. He also notes that they were fabricated in various seaports by ingenious men and offered for sale as "poissons singuliers"—which they certainly were.

These fabricated and dried rays were fairly common in the private museums of the seventeenth and eighteenth centuries. Thus Filippo Bonanni in his book, "Museum Kircherianum," Romae, 1709, describes one in Athanasius Kircher's museum in the Jesuits' College at Rome. From Bonanni's description, this specimen must have been almost identical with Duhamel's. Then in C A Calonne's sales catalogue of his Museum Calonnianum (London, 1797), there is listed this item:



—*Courtesy of Mr. Walter F. Heintzelman*

FIG. 14. AN AMERICAN JENNY HANIVER

HAND-CARVED AT ASBURY PARK, NEW JERSEY, IN MAY, 1929.

—*Courtesy of Mr. Howard C. Trout*

FIG. 15. AN UP-TO-DATE JENNY HANIVER—1933 MODEL

MADE IN FLORIDA FROM A GUITARFISH.

Young-maid—Normandy—*Raia clavata* Linn. This has been bent so as to represent a dragon, and has even, in this state, been figured by authors and called the Sea Eagle [Aquila marina of Belon, 1553], Fig. 4.

Since writing the above, my attention has been called to papers by the Italian writers, Forti, Ninni and Parisi, describing various basilisk- and dragon-like artifacts, made of dried sharks and rays, preserved in the museums of Milan, Venice and Verona. Probably there are others in other public and private museums in northern Italy, for Parisi states that they were manufactured in numbers in Italy during the sixteenth century. Some of these seem to have belonged to Aldrovandi's museum, and there are MS. notes of his on "Dracones," etc., preserved in the library of the University of Bologna. These figures are too numerous to add to this paper. Perhaps they can be worked up in another article later.

MORE MODERN JENNY HANIVERS

From the modern specimen from Brooklyn shown in Fig. 1, one needs seven-league boots to stride quickly to Sydney, Australia, where in 1928 the ichthyologist, Whitley, published in the *Australian Museum Magazine* an article on Jenny Hanivers. This was illustrated not merely by three of the old figures given above, but by photographs of two modern forms. That reproduced herein as Fig. 13 is the Jenny Haniver brought from Whitby, England, by Dr. R. Mead, who has been quoted above (p. 511) This has the wings wrapped tightly around it over the back, but the mouthparts are pulled out into a snout very like those shown in Fig. 1, also a present-day specimen. The other monster was made for Mr. Whitley by a New South Wales trawler. The wings are folded back across the body, but the spread of the hinder fins recalls the like in Fig. 8. The snout is very similar to

that in Belon's "Marina Aquila" of 1553 (Fig. 5), and Rondelet's "Monstrosi Piscis Volantis Imago" (Fig. 6). Whitley's figure will presently be contrasted with that of another up-to-date Jenny Haniver.

We are now come to a present-day attempt to make an American Jenny Haniver, and here is its story, sent out by the Associated Press from Asbury Park, N. J., on May 4, 1929. This dispatch in part reads as follows:

> A fish with a "human face," slightly mongoloid and a bit weird but none the less a face, is the prize catch of Julius Gabriel, cobbler-fisherman of Allentown, Pa . . . The creature has a large mouth, the interior of which is much like that of a human's. It has what appears to be eyes properly set with respect to the mouth, and a suggestion of a nose The broad flap of heavy flesh makes up a high forehead, suggesting an odd head-dress. Below the head and neck the body takes on the appearance of a human being with a well-developed chest. *It has a long tail* with spines developed along the entire length [Fig. 14].

The statement being made that the monster had been examined by scientists of Muhlenberg College, of Allentown, Pa, I got in touch with Professor J F. Shankweiler of the department of biology at the college. One of his students, Mr. Walter F. Heintzelman, saw and photographed the fish shortly after it was taken and after the pectoral fins had been cut free from the head, as Fig. 14 shows. The fish was about 28 inches long "over all" and about a foot wide. The photographs and accounts sent me by my informants revealed the curious fact that here was an attempt by an illiterate man, who had surely never heard of a Jenny Haniver, to reproduce those made in the fifteenth and sixteenth centuries.

Now comes the latest of Jenny Hanivers—1933 model. I had thought the Asbury Park specimen the latest thing in Jenny Hanivers. My article had been finished and was waiting to be typed when Mr Howard C. Trout of Jarvis Avenue, the Bronx, came to my office bringing the curious object por-

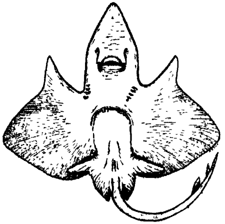
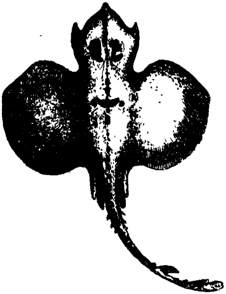


FIG 16. VENTRAL ASPECT OF AN ABNORMAL BARN-DOOR SKATE

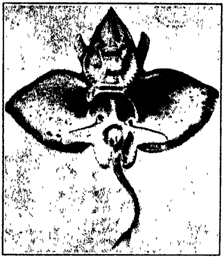
THIS ADULT SKATE IS A PERMANENT LARVAL FORM IN WHICH THE FINS ("WINGS") HAVE NEVER BECOME ADHERENT TO THE HEAD.



—After Yarrell, 1859

FIG. 17. A NATURE-MADE JENNY HANIVER

THIS HAS HORNS AS WELL AS NON ADHERENT PECTORAL FINS.



—*After Otto, 1821*

FIG. 18. VENTRAL ASPECT OF ANOTHER ABNORMAL RAY. THIS WOULD HAVE MADE A FINE JENNY HANIVER

trayed in Fig 15. This Jenny Haniver is made of a manipulated, dried and painted guitarfish, *Rhinobatus lentiginosus.* Mr. Trout recently secured it at Miami, Florida, from a Swedish fisherman, who had made it some two months previously. Neither he nor any of the fishermen who looked on had any knowledge or motive other than to take the faint resemblance to a human figure and so manipulate the fish as to accentuate this.

The tip of the snout has been bent backward (or upward as the fish rests on the bottom). The double nostrils have flared wide in drying. Above them and near the rostral cartilage, eyes have been pencilled. The mouth has been pulled forward and distended. The pectoral fins have been folded back and the point of each rolled up like a scroll. The neck-region has been constricted. The appendages of the pelvic fins of this male fish have been brought together to simulate legs. And finally the tip of the snout, the neck region and the legs have been painted an orange-red.

How Nature Makes Jenny Hanivers

There are occasionally found in nature adult rays in which the pectoral fins never grow fast to the sides of the head—retaining the embryonic condition. This comes about because rays in the course of their development go through all the stages of their shark ancestors The stage of particular interest here is that in which the pectoral fins ("wings" so-called) have not yet become adherent to the sides of the head, as is normal in rays, but remain free as in sharks Some rays retain this as an adult character but a teratological one—*i.e*, they remain throughout life as permanent larval forms, as may be seen in Fig 16, a drawing of a specimen in my possession. Such rays would easily lend themselves to the making of the Jenny Hanivers figured herein, particularly Figs. 7 and 8. Three figures now to be introduced show how these and other man-made artifacts might have had an origin in nature.

In Fig 17 is shown from Yarrell's British Fishes (3rd ed., p. 584, 1859) a

—*After Paolucci, 1874*

FIG. 19. A HORNED CYCLOPS RAY

THIS WOULD HAVE SERVED AS THE BASIS FOR A MOST REMARKABLE AND WEIRD JENNY HANIVER.

portrait of a monstrous thornback maid (*Raja clavata*). Here there are two failures of the pectoral fins to unite with the head. The first left the small lateral horns, and the second the wider notches lower down. If a Jenny Haniver-maker could have gotten hold of this specimen he surely could not have improved on nature very much. Note that this ray is figured as seen from above.

Even more weird is the ray portrayed in Fig. 18. This, the first adult ray with non-adherent wings ever figured and described, was obtained by the Breslau naturalist, Otto,[2] from a fisherman at Edinburgh, in 1818. Otto did not recognize it as an abnormality, but thought it a new kind of rayfish and gave it new generic and specific names. The round form of the under surface of the head, and the conformation of mouth and nostrils give it a rather human appearance, while the remnants of the pectoral fins somewhat resemble ears or perhaps hands in that position called for in the present-day oft-repeated command—"Hands up!"

Weirdest of all is Paolucci's horned and cyclops-eyed *Myliobatis noctula*[3] (Fig. 19). It is something wherewith to scare children and even grown-ups. The short horns and the sinister single eye of this monster between them, with the broad mouth below, combine to produce an apparition the weirdest and most abnormal in my collection of figures of such teratological rays. Its specific name, *noctula*, indicated that it went abroad only in the dark—as it surely should. From it could have been fabricated a most marvelous Jenny Haniver.

[2] Paolucci, Luigi. Atti Soc. Ital. Sci. Nat., 1874, vol 17, pp. 60–63, figs

[3] Paolucci, L. Atti Soc. Ital. Sci. Nat., 1874, 17, 60–63, pl.

RULING THE RIVER

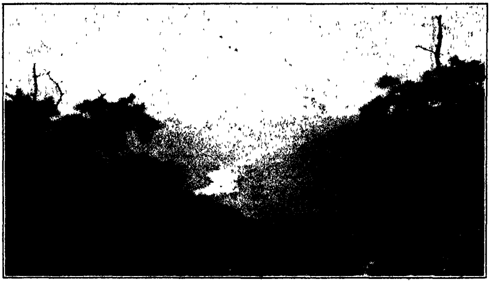
By REGINALD D. FORBES

IN his pioneering plans for the all-around development of the Tennessee Basin and other valleys, President Roosevelt has stressed the importance, as a first step, of practising forestry in the mountains. The ancient Japanese proverb, "To rule the river is to rule the mountain," evidently appeals to him as good common sense, in spite of the scepticism rampant in some American scientific circles as to the existence of any appreciable influence of forests upon the flow of our streams. This scepticism has found vigorous and often acrimonious expression in the press, and has at times threatened to develop a major controversy between professional men and among public agencies.

That the President's views are based on first-hand knowledge of the forest is apparent from a story told by the secretary of the Society of American Foresters. A summer or two ago the New York section of the society visited the Roosevelt estate at Hyde Park to see the forestry operations under way there. After their inspection of the woods the foresters were invited to meet the governor informally on the lawn of Krum Elbow. To their delight his welcome was not a perfunctory five-minute speech, confined to generalities, but an illuminating twenty-minute discussion of some of their professional problems. It showed such evident grasp of a specialized subject that a cynic in the crowd whispered to the state forester beside him: "Which one of you foresters wrote the Governor's speech for him?" A few minutes later the official addressed, thinking the joke too good to keep, repeated the question to Mr. Roosevelt. Whereupon the governor, with a twinkle in his eye, turned to his attendant. "Sergeant," he said, "what did I ask you when we came out on the terrace half an hour ago?" The man grinned. "Why, Governor, you said to me: 'Sergeant, what the devil am I going to tell these boys?' "

EARLY CONTROVERSIES

The belief that forests exert a favorable influence on stream-flow was first publicly expressed in the United States in connection with the acquisition and administration of the national forests. Only 70 of the 150 million acres set aside in such forests from the public domain of the West bear commercial timber The remaining 80 million are, nevertheless, given protection against fire and excessive grazing, because of their location on the watersheds of streams having enormous value for irrigation and other purposes. By those who see nothing in the conservationists' claims this has been described as a great waste of public funds. For example, a former chief of the Weather Bureau has said: "For years an extensive propaganda has been carried on in the United States for the purpose of inducing large public appropriations not only to protect the real forests of the nation, which every right-thinking person wishes to have protected and wisely conserved, but also millions of acres of bush lots and scrub timber that can never grow anything of value. The reason given by forest enthusiasts for such expenditures is that this otherwise worthless vegetation protects the water supply of great centers of population. But I know of no scientific reason to justify their claims." The foresters' arguments in favor of a beneficial influence of forests on stream-flow to him seem "—the hysterical screams of interested office-holders who



"TO RULE THE RIVER IS TO RULE THE MOUNTAIN"
SCENE FROM A FORMERLY FIRE-SWEPT MOUNTAIN, NOW PART OF THE ALLEGHENY NATIONAL FOREST, PENNSYLVANIA.[1]

wish only to retain their jobs of protecting worthless vegetation. They hope so to alarm honest people with forebodings of impending disaster that large grants of public money will be forthcoming to increase their personal emolument and hire additional defenders."

In spite of this early opposition within the Department of Agriculture itself, public opinion has not only sustained the National Forest system, but has also enlarged it. The Weeks Act, passed in 1911, authorized the purchase of lands for national forests in the East, where little or no public domain still existed, and specified that such lands be "located on the head-waters of navigable streams or those which are being or which may be developed for navigable purposes." The Clarke-McNary Act, which, in 1924, superseded the Weeks Act, prescribed that in future purchases "due consideration shall be given to the protection of watersheds of navigable streams, but—may be—extended to any timbered or forest-producing lands or watersheds from which water is secured for domestic use or irrigation" Several million acres have been added to the national forests under these two acts.

[1] Photographs by courtesy U. S. Forest Service. California photographs by W. C. Lowdermilk and P. B. Rowe.

FORESTS AND THE MISSISSIPPI FLOODS

The Mississippi flood situation has been another occasion for the published expression of widely divergent views on forest influences. In 1925 an army officer of high rank compared records of precipitation over a portion of Wisconsin, on the headwaters of the great river, with the flow of streams there, from the time when the virgin forests were still intact down to 1924. He concluded: "I maintain that land, cleared of timber and gone back to scrub—is equal to, if not greater than, the original forest in reducing run-off. As more of this land goes under cultivation the run-off will be less. This brings me to my early theory that farms are better than forests in re-

ducing run-off." The same officer, as chairman of the Mississippi River Commission in the year of the worst disasters in the history of the river—1927—announced that "*after exhaustive studies* covering the advantages and limitations of reforesting, reservoirs, cut-offs and outlets, as steps toward reducing flood heights, it was decided that levees afford the *only* practicable means for flood control in the lower Mississippi Valley." (The italics are mine.) Subsequent commissions have but slightly and grudgingly modified this view.

Very different were the conclusions reached by the Department of Agriculture after a Forest Service investigation of the 1927 flood. Without denying in the slightest degree the necessity for engineering works in the control of the river, Secretary Jardine reported that ". . . the forests of the Mississippi watershed were responsible for a reduction in the possible flood crest of nearly 15 inches. Furthermore, were all the forests of the Mississippi Valley properly protected and managed in accordance with established principles and practises, a further reduction in possible flood crests of 55 inches would be possible. Thus the results, even when based on acknowledged incomplete and conservative data, are of such significance that it does not seem possible that the part the forests play in the control of floods can be longer ignored."

If a foot—or six feet—on the crest of a stream having a flood depth of a hundred and fifty feet seems rather trifling, be it remembered that it is the last few feet that bring destruction and terror to the lowlands. No one who has ever stood on the levee which protects his home and has watched the inexorable rise, inch by inch and hour by hour, of the brown waters bringing disaster and perhaps death, can ever belittle the last few feet of that rise. It may be, indeed, that no levee ever gave way at the top, but it was the weight of the final flood crest that caused its collapse.

IDEAL PROTECTION AGAINST BEATING RAINS.
THE HUMUS IS HALF A FOOT DEEP BENEATH THIS VIRGIN HEMLOCK FOREST.

GUARDIANS OF THE TENNESSEE WATERSHED.
A MOUNTAIN HARDWOOD FOREST.

FOREST INFLUENCES A COMPLEX PROBLEM

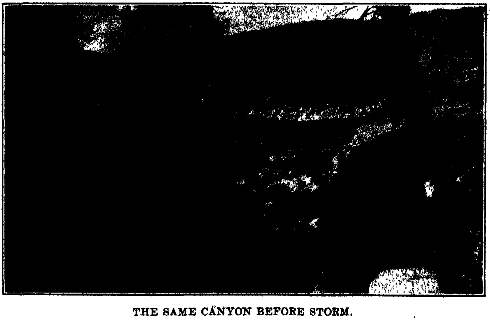
How can such divergent views be held among scientific men? How can some deny to the forest any influence at all upon stream-flow, and others as stoutly maintain that the influence is great? Essentially, it is because the relationship is an extremely complex one, and because under the great diversity of physical conditions in the United States generalizations from limited or local information are rarely possible. Approached from single angles, the problem yields many answers. That is why the experiment stations of the Federal forest service, in studies only recently begun, have attempted to subdivide the problem and to dig down to fundamentals in its solution. Some of the still fragmentary information already gained by them is the chief basis for the statements in the remainder of this article.

The behavior of any stream—whether it is steady in flow throughout the year, or now in flood and a few months later dry—depends on three things—the climate, the geology and the vegetation of the region from which it flows.

Of the climatic factors, precipitation, mostly rain or snow, is of course all-important. In a country as large as the United States there are enormous variations in yearly precipitation. The valleys of southern California are populous, in spite of a yearly rainfall of less than ten inches. At the very summit of the Blue Ridge in the Carolinas and Tennessee the precipitation is 80 inches, and on the western slopes of the Cascade Mountains in Oregon and Washington the yearly average is 120 inches. The low California rainfall is largely concentrated in a single rainy season, whereas the vastly more abundant rain or equivalent snow of the two mountain regions is rather evenly distributed through the year. The behavior of the streams of these regions inevitably reflects these differences in total and seasonal precipitation.

The quantity of rain or melted snow which soaks into the soil of mountain slopes, to reappear, often months later, at the surface as springs and streams, is dependent on the depth and porosity of the soil, and on the character of the underlying rock. In shallow soils the quantity of stored water may be very

CANYON FILLED WITH SEDIMENT FROM SINGLE STORM OVER BURNED WATERSHED, SOUTHERN CALIFORNIA.



THE SAME CANYON BEFORE STORM.

slight. But in most regions the water slowly moving through the soil is infinitely greater in quantity than that stored above ground in lakes and ponds. Underground storage has the great advantage over surface storage that it is not nearly so subject to evaporation. In southern California, for example, where fully 80 per cent. of the water for irrigation is pumped from underground storage basins at considerable depths, the evaporation from a water surface greatly exceeds the yearly rainfall, whereas from a bare soil it may be only 50 to 80 per cent. of the rainfall.

Degree of slope has been rather unexpectedly found to have little influence on the rate at which precipitation soaks into the soil, although it has a very profound effect on so much of the water as, unable to penetrate the soil, runs off over the surface.

The first two factors—climate and geology—which influence the flow of streams are for the present at least beyond human power to control. But the third factor—vegetation—man has it in his power to alter and even destroy. Through such agencies as axe, saw, fire and the excessive grazing of domestic animals the people of the United States have tragically altered the vegetation of the greater part of our vast territory. We have cleared the original vegetation, either forest or prairie sod, from some 500 million acres needed for agriculture, and, as we are only now beginning to realize, have done a very indifferent job of replacing it with an artificial vegetation equally capable of preventing serious washing of the soil. Erosion of farm lands has been characterized by the United States Bureau of Chemistry and Soils as a national menace. Another 400 million acres, not needed for agriculture, we have not only stripped of its virgin timber, but have also permitted in greater part to burn over, thereby reducing a once magnificent vegetative mantle to a pitifully thin one. We have not even spared the woodland, the chaparral, the sparse herbs and grass of the drier parts of the country, but have ravaged them with fire and in places all but exterminated them with over-grazing by our domestic animals.

The Rôle of Forest Humus

The result of these actions of ours can best be understood from a knowledge of how the undisturbed forest affects the flow of streams. First and most important of all, the forest decreases the proportion of rain and melted snow which runs off over the surface of the ground. Water which sinks at once into the soil and reaches the streams by slow percolation, being held temporarily in the myriad spaces between soil particles and in the crevices of rocks, rarely causes erosion, and perhaps never causes disastrous floods.

Why rain beating upon bare soil is not readily absorbed has been clearly demonstrated by a simple laboratory experiment of Dr. W. C. Lowdermilk, of the California Forest Experiment Station. He filled tall glass jars with soil, and allowed clear water to percolate downward through the soil columns for several hours. The rate of flow was very constant, and undiminished with time. He then muddied the percolating water with some of the fine surface material typical of these soils. Within six hours the rate of flow dropped to 10 per cent. of what it had been. The fine soil particles, carried downward in suspension, had clogged the pores of the upper soil layers, and permanently ruined the absorptive capacity of the soil. Dr. Lowdermilk points out that rain beating on an unprotected soil is inevitably muddied, and, acting like the muddied water in his jars, promptly renders the soil beneath impermeable.

If the ground in question is flat, the water simply accumulates on the sur-

YESTERDAY A TORRENT, TO-DAY A TRICKLE.
PROTECTIVE VEGETATION EXTERMINATED BY SMELTER FUMES. TENNESSEE.

face. But if the ground slopes, it rushes down hill, eroding as it goes, and swelling even normally tiny streams into torrents. Thus the Southern Station, working on the upper watershed of the Tallahatchie River in Mississippi during the great Yazoo Delta floods of two years ago, found that in the heaviest rains 95 per cent. of the water ran off the surface of cultivated land, protected only by the stubble of the previous season's corn crop. During a ten-week period an average of 62 per cent. of all rain ran off the surface, carrying with it 34 tons of soil an acre! The surface run-off of summer rains from more permeable soils in Wisconsin was found by the Lake States Station to be about 25 per cent., in spite of the protection afforded by a growing crop of corn or other grains.

In strong contrast with the soil of clean-cultivated fields, the ground beneath a dense forest is never bare. It is carpeted by a layer of fallen leaves, twigs and other plant material in all stages of decay—forest humus. Until recently the chief rôle of forest humus in preventing rapid run-off was believed to be its capacity for absorbing water. Humus will absorb three or four times its weight of moisture; in a hardwood forest, such as that of the southern Appalachian Mountains, this absorption under favorable conditions has been found to equal a quarter of an inch of rain. But this effect on run-off is probably quite insignificant when compared with the ability of humus to keep falling rain clear, and thereby to allow its uninterrupted passage into the soil beneath. In the Mississippi and Wisconsin studies just referred to *less than 3 per cent.* of the rain ran off the surface of forested land. Recent experiments at the Cen-

tral States Station have demonstrated that water sinks much faster into the naturally loose, humus-covered soil beneath a forest than into the artificially loosened soil of adjacent fields.

But this is not all that forest humus does to promote storage of water in the soil. Acting as a mulch, it retards evaporation. Again, the fine particles of humus, carried downward by percolating water, enormously increase the moisture-holding capacity of soils. Five per cent. of such material will increase the water-holding capacity of a coarse sand by 40 per cent. The humus derived from dead roots has the same effect.

OTHER FACTORS IN FOREST INFLUENCES

The major influence of the forest on streamflow is unquestionably exerted by the humus. But there are other important influences. For example, a very substantial proportion of the rain falling on a forest is prevented by the leafy crowns from reaching the ground. Have you ever taken refuge from a shower under a tree? You then know that a light rain may be completely intercepted by the dense foliage of some tree species. The Pacific Northwest Station found this to be true in a mature Douglas fir forest, and that of an entire summer's rainfall over a third may be intercepted in the crowns. In a dense sapling stand the percentage intercepted is even higher.

Again, evergreen forests have been found to delay the melting of snow in the spring. In those parts of the United States where snow accumulates to depths of several feet, and particularly where snow is the important part of the year's precipitation, the rate of snow melt is doubly important. If the snow melts all at once, and before the frost is out of the ground, floods cause havoc, and much precious water fails to reach the underground storage basins for summer use, generally the irrigation of farm lands. Although the total accumulation of snow may be less under a forest canopy than in the open, due to interception of the falling snow by the tree crowns, late in the spring a substantial amount remains there a week or two after it has disappeared from open ground. Because the spring thaw, once begun, is rapid, this brief delay permits much of the winter's precipitation to be absorbed in the ground, instead of running off the surface.

Melting is delayed partly by the shade of the tree crowns, but probably more by the lessened movement of drying winds. In a northern Idaho valley a full stand of western white pine and larch reduced the wind movement during the fire season to only one twenty-fifth of that in a logged-off area adjacent. Evaporation within the forest was in consequence only one sixth of that in the open. Reduction of evaporation of course means that once precipitation has entered the ground more of it will eventually find its way into streams.

Below ground, the dead and decayed roots of forest trees form channels for the penetration of water into the soil, and by adding to the invaluable humus content promote water storage. On the other hand, living roots withdraw vast quantities of water from the soil. The water taken up by the roots is carried up to the leaves and combined with carbon dioxide from the air to form plant food, under the influence of sunlight. In the process water is transpired into the air. C. G. Bates, of the U. S. Forest Service, experimenting with potted 5 and 6-year old seedlings of Rocky Mountain evergreens, reported that to produce a gram of dry substance these seedlings required an average of 880 grams of water. But the water transpired by an entire forest of mature trees is impossible to measure by any such laboratory experiments as those used in the study of seedlings weighing a few grams. Even European foresters have made

nothing more than estimates, which place the annual loss by transpiration from temperate zone forests at 10 to 50 per cent. of the rainfall.

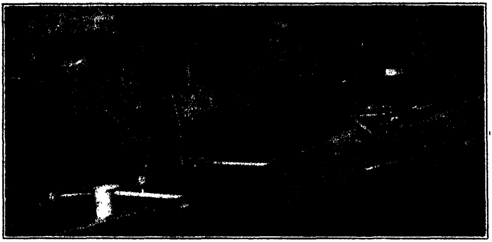
Regional Variations Important

The net effect of all these influences of the forest upon streamflow will obviously differ from region to region and from season to season. Under all conditions the nearly complete prevention of surface run-off by a dense forest and heavy humus is enormously beneficial, because of lessened soil erosion. Its corollary—increased absorption and storage of precipitation in the soil—fails to be wholly beneficial only in so far as the stored moisture is transpired into the air by the trees, instead of contributing to the dry-season flow of streams. The same is true of retardation of snow melt.

Whether the interception of rain and snow in the tree crowns, their absorption by the humus, and their return to the atmosphere through transpiration, are beneficial or detrimental depends upon the region and to some extent the season. In the southern Appalachians, with their normally high and well-distributed rainfall, generally deep soils and steep slopes, floods appear to result from a succession of heavy storms separated by short intervals of fair weather. Under such conditions all the factors which operate to reduce the amount of water reaching the streams after each storm combine with the prevention of surface run-off to make the forest indispensable to well-regulated streamflow. The President is on particularly strong ground when he insists that forestry be practised on the headwaters of the Tennessee River. The annual loss from floods, many of them on this stream, in the state of Tennessee averages $1,000,000 a year.

But in a region of relatively low rainfall, concentrated in a rainy season, reduction in the total run-off caused by forest or other vegetation is distinctly detrimental, and to be tolerated only if offset by the favorable influences of the forest. Southern California is such a

APPARATUS FOR MEASURING SURFACE RUN-OFF AND EROSION. SOUTHERN CALIFORNIA.



MEASURING EFFECT OF DENUDING FORESTED SLOPES, CALIFORNIA.

region. Here water for irrigation and even domestic use is of vital concern, the available supply limiting the further development of an otherwise rich region Only recently, studies of precipitation and streamflow records, chiefly from this region, have led engineers of the U. S. Geological Survey to question "whether the value of increased water supply and better-sustained minimum flow which are shown to obtain without forests, does not outweigh the benefits of lowered normal flood flows and decreased erosion produced by forests." Foresters have replied that the chaparral, or "elfin forest," which covers 97 per cent. of the southern California watersheds, and which, as they have demonstrated, minimizes surface run-off and erosion, prevents only a very small amount of water from reaching the streams. During the season of greatest rainfall it intercepts almost no rain and is not actively transpiring, being leafless. The cottonwoods, willows, sycamores and alders of the canyon bottoms, on the other hand, although occupying but 3 per cent. of the area, are tremendous users, all summer long, of the water which concentrates in their habitat from the surrounding hills. Fortunately it is a comparatively simple matter to pipe the water around the canyon groves, and thus save it for human use. As for the fact, pointed out by the engineers, that burning off the hill vegetation increases the summer, or low-water, flow of streams, records show that even the increased flow is less than 5 per cent. of that for the entire year.

What Is Needed

Quite evidently what America needs in the conservation of her enormously important water resources is not more controversies, but more facts. The foresters' studies, backed by Old World experience, have already established the general fact that forests improve streamflow. But very specific knowledge is required by engineers who design storage dams, plan flood control works and devise stream improvements. Such knowledge may be gained only by further research in which all the complex factors of climate, geology and vegetation are evaluated. To this end engineers, meteorologists, geologists, soil experts, botanists and foresters must join hands.

LANAO—LOVELY LAND OF ROMANCE

By Dr. ALBERT W. C. T. HERRE

CURATOR, MUSEUM OF ZOOLOGY, STANFORD UNIVERSITY

"ROMANCE, romance, romance," runs the refrain in a popular song of yesteryear, and so beat the heart throbs of countless millions of people in every land. The overwhelming majority of men and women, boys and girls, of every tongue and every clime, crave something outside the humdrum of their everyday existence. They long for something unknown, they know not what, and impute to the little known, the bizarre, the exotic, strange esoteric qualities that are the very quintessence of romance. The city lights lure thousands, but others are attracted to ice-capped Antarctica or the unexplored jungles of New Guinea, where cannibals and birds of paradise enliven the forest.

Not all realize that romance exists as well in the test tube and retort and casts its purple glow across the bacteriologist and microscopist. It is apparent in the study of electricity and in the work of the field naturalist, whether botanist or zoologist, while even the man in the street knows that romance is an integral part of the life of the geologist and anthropologist.

Through all the ages people have seen adventure and romance wherever alien tongues, strange customs and different religions prevailed. When these are placed in a setting of tropical jungle, with its strange enormous plants, dazzlingly brilliant birds, teeming insect life, gigantic snakes and chattering monkeys, people of northern climes are ready to believe almost any fantastic yarn.

The East Indies are a typical region of romance. For untold centuries adventurers and hellions of all sorts have gone there as pirates, merchants, missionaries (Hindu, Buddhist, Mohammedan, Christian), conquerors, wonder-seekers, and so on. Hindus, Cambodians, Siamese, Chinese, Japanese, Arabs, Portuguese, Dutch, Spanish, English, all explored, traded, raided, looted, converted, while among themselves the Malays did the same and more. Great empires arose, only to fall centuries later in that world of islands, and the commerce of all nations paid tribute to the pirates of Illana Bay and Tawi Tawi down to the memory of living men.

That northern spur of the East Indies which we call the Philippines is one of the most interesting of all the island groups. Its highly varied population includes the Negrito with no permanent habitation, the Manobo and Ilongot tree dwellers, and all grades of society up to the cultured and cosmopolitan graduates of great American and European universities who would ornament any social circle.

For many years I have been intimately acquainted with one of the most intriguing portions of the Philippines. It lies in Mindanao, that great island known to white men for more than four hundred years, but still containing unexplored areas and a wealth of life offering rich fields for scientific investigation.

The area to which I refer is the mountainous plateau of Lanao, one of the "Moro" or Mohammedan provinces. This region has a reputation for "battle, murder, and sudden death," but in reality is as safe as cities in the United States.

Lanao is in the west central part of Mindanao. Its north coast is bathed by Iligan Bay and it extends southward to Illana Bay, a part of the Sea of Celebes.

Most of the province, which has an area of 2,722 square miles, is a mountainous plateau, with a very narrow fringe of coastal lowland.

The mere tourist carries from Lanao memories of brilliant sunshine, interspersed by daily thunder showers, nights of refreshing coolness, and withal a colorful bizarre glimpse of strange people living about a great jewel-like lake in a setting of lofty forested volcanoes. But Lanao is worth far more to a scientist than merely a two- or three-day visit. At the risk of too much detail, let us note some of the attractions of Lanao.

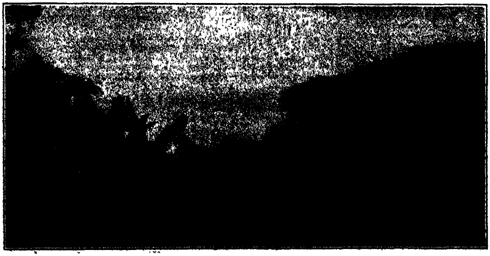
The dominant feature of the region and the one that gives its name to the province is Lake Lanao Lanao is the Marinao word for lake, and either as danao or lanao occurs in many Malayan languages. Lake Lanao is therefore a redundancy, but I see no way to avoid using the term. The lake is a fine open expanse of clear water, covering 145 square miles and lying at an elevation of 2,100 feet.

To reach the lake one ordinarily lands at Iligan on the north coast of the province. From here an excellent automobile road ascends to the lake. As the sea coast is left one is almost sure to see a family group of monkeys crossing the road, which skirts a deep and heavily forested canyon. At the head of the canyon a brook leaps down about 400 feet, forming a small but very lovely waterfall.

Gaining the plateau, one travels over rolling hills, denuded of trees and sprinkled with the small farms of the natives.

As one climbs the last ridge and enters Camp Keithley he is impressed by the wide open spaces and the unobstructed view across the lake and beyond. Villages on the eastern and southern shores, ten to twenty miles away, are plainly visible. Then leaping over a few miles of intervening low land, one's eyes rest upon the lofty volcanic peaks of the Butig range, which rise to an elevation of over 9,000 feet and are clothed to their unexplored summits by the densest sort of primitive dipterocarp rain forest.

Between Camp Keithley and Dansalan, the provincial capital, is the outlet of the lake, the furiously rushing Agus, which races and roars, leaps and tosses madly in headlong speed to the sea. Not far from its mouth the Agus makes a



VIEW OF LAKE LANAO FROM THE GROUNDS OF THE LUMBATAN FARM SCHOOL

plunge of 65 meters over the precipice at the head of a box canyon, forming the picturesque Maria Cristina Falls.

The present province of Lanao was originally a coral reef which later was raised a few hundred feet above the sea. Upon this ancient reef, lava flows and great deposits of volcanic ash were superimposed.

Lake Lanao was formed when a deep mountain canyon was dammed by a lava flow. Gradually the mountain torrent thus checked filled the gorge and in time spread over the tableland eastward, thus creating the present lake. Not far from the outlet I found a depth of 150 feet in the lake, and at the head of the ancient canyon the military cable survey found a depth of 900 feet. This was near Bayong, on the southern shore. Over most of its eastern half Lake Lanao is comparatively shallow, and thousands of acres near the eastern shore are covered by only two to five meters of water.

Lake Lanao contains a unique and highly interesting fish fauna, which I discovered some years ago while making a reconnaissance of its aquatic life. I have thus far described seventeen species of Cyprinidae from the lake. They belong to four different genera, three of them new.

These seventeen species of Cyprinidae are all descended from a single parent species, which is found all over Mindanao and throughout Malaysia west of Lombok and Celebes. Elsewhere I have discussed this remarkable demonstration of evolution here and now.

In addition to the above, Lake Lanao contains an eel (*Anguilla celebesensis*) and one species of Ophicephalus (*Ophicephalus striatus*). The latter was introduced by man long, long ago, as I have shown in the case of several other lakes.

Eels of the family Anguillidae breed only in the deep sea far from land. Their presence, therefore, in the lake is

IN A MARINAO VILLAGE ON THE EASTERN SHORE OF LAKE LANAO.

HOUSE OF A MARINAO DATU.
NOTE THE CARVED ENDS OF THE FLOOR JOISTS WHICH ARE HEWED PLANK SOMETIMES THIRTY OR FORTY FEET LONG.

CLOSE UP OF THE ELABORATE CARVING CHARACTERISTIC OF THE HOMES OF WEALTHY MARINAO. THE INTRICATE DESIGNS ARE CHISELED IN THE HARD WOOD.

rather puzzling. When the young elvers enter the coastal streams from the sea it is manifestly impossible for them to ascend any with a waterfall such as the Maria Cristina. Careful observation of the talus slopes along the canyon walls below the falls reveals the presence of many streamlets and gouts of water spurting from the cliffs at the top of the talus. I believe that the young eels climb the talus and creep through these water-bearing crevices, to emerge in the river well above the falls.

As already pointed out in *The American Naturalist*, the cyprinid fishes of Lake Lanao offer an unexcelled opportunity to the student of evolution, particularly to those who desire to make statistical studies. Needless to say, the lake also presents a nearly virgin field for the hydrobiologist who is really desirous of studying aquatic life of all kinds under almost ideal conditions.

For a totally different kind of an environment, let us land at Tamparan, on the eastern shore of the lake. Three hours of steady walking through the rice fields will bring one to the edge of the cleared land, and before long the last homestead will be left behind. From then on there is only the unbroken primitive forest extending to the other side of the mountains. At first one sees where rattan gatherers have been at work or some one has taken out a tree for some special purpose, but gradually one draws into the sort of jungle that grows only where almost daily rains stimulate the growth of vegetation, and practically all trace of man disappears. The single trail crossing the Butig mountains is rarely traversed. When I saw it last it had almost disappeared from view and was nearly impassable from windfalls, landslides and the rapid growth of tropical plants. Rugnan, at the summit of the pass at an elevation of 5,000 feet, is said to be the coldest spot in the Philippines.

This great forest and its untrodden volcanic peaks hide many botanical treasures as yet undiscovered. Deer and wild pig are plentiful, and often at night one may hear the death squeal of a luckless shoat as some gigantic python snatches him up from the ground. Family parties of monkeys roam freely through the intertwining tops of the great trees, or scamper madly away from the deadly swoop of the swift and powerful monkey-eating eagle, perhaps the largest and strongest of his tribe. One rarely sees any of the beautiful birds concealed in the world of light atop of

the trees, but now and then in the gloom of the forest one is thrilled by a rippling burst of song from some invisible bird. It is high up in the trees, too, that the great land snails, with their lovely shells, are found.

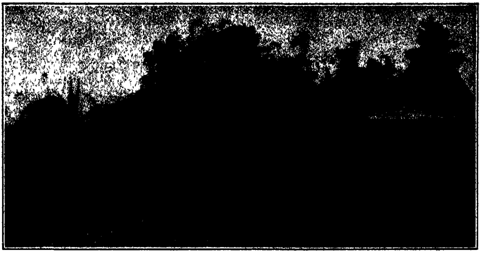
On the ridges south and southeast of Lake Lanao, especially those looking down on Lake Dapao, grows the largest bamboo in the islands. It is a delight to wander in the shade of giant clumps of this Brobdingnagian grass or traverse the dim aisles formed by its eight-inch stalks arching sixty to ninety feet above. On the wild trail to Lake Nunuñgan, sprinkled amid the gigantic wild bananas, is an undescribed pandan which strides on its impossible looking stilt roots across the dripping wet mountain swales and rears its flamboyant head fifty to eighty feet above the earth.

During the greater part of the year there are land leeches in all the forests, whether on the slopes of the Butig mountains, on the Nunuñgan trail, or southward down to Malabang. Land leeches are very, very slender liver-colored creatures about an inch long, always hungry, and very active in the pursuit of prey. To watch countless numbers waving their blind heads to and fro as they stand erect and try to locate possible prey, or see them go looping their way unerringly toward approaching animals, is a shivery experience. Fortunately, if one dresses properly, *and is sufficiently vigilant,* he can avoid their attentions. It is pitiful to see them distended with blood and looking like bunches of grapes hanging around the ankles of barefoot porters or on the fetlocks of horses. Once in rainy weather I thought to avoid them by riding horseback, but to my astonishment beautiful longitudinally striped green and gold leeches dropped from the trees above and promptly proceeded to levy tribute.

Near Bayong the tourist sees enor-

A RIVAL WAR PARTY AT MASIU

READY TO FIGHT OVER THE SUCCESSION TO THE SULTANATE OF MASIU. THE AMERICAN AT THE RIGHT OF THE CENTER IS MR. C. O. DOUGLAS, TEACHER AT LUMBATAN.



A WAR PARTY ASSEMBLED AT MASIU IN 1925.
NEARLY 200 HEAVILY ARMED MEN WITH A MARVELLOUS AGGREGATION OF BLADE WEAPONS WHICH THEY WERE ACHING TO USE.

mous leafless trees covered with strange-looking, large, pear-shaped "fruit." I once overheard a party of American and Tagalog tourists arguing about this fruit. When I told them the fruit was merely gigantic fruit bats they were very skeptical until a shot caused them to take flight. These fruit bats have a wing spread of three to five feet and fly with the slow labored flight of a tired crow, instead of the erratic swift flight familiar in other bats.

Since "the proper study of man is mankind" the Marinao, as the people of Lanao call themselves, would well repay careful investigation.

The Marinao are undoubtedly of the same general stock as their neighbors, the Bukidnons and Manobos, but were converted to Mohammedanism a long time ago, probably in the fourteenth century. The advent of the new religion brought a higher culture, and the slight but definite contact with Arabia maintained through all the succeeding centuries by those making the pilgrimage to Mecca has emphasized and strengthened their advance above the surrounding pagans.

The Marinao, secure in their mountain fastnesses, were always a turbulent and independent breed, as touchy as Gaelic or Southern Appalachian clansmen. As a result they never developed a strong government or a central authority. Datus, or hereditary chieftains, are very numerous and there are several petty "rajahs" and four "sultans." No Spanish grandee was ever more conceited over his lineage than are the Marinao aristocracy, who trace their ancestry back to the "Arab" adventurers who brought them Mohammedanism.

The homes of wealthy Marinao are notable for their unusual architectural decorations. The floor joists, made of very hard wood, project several feet beyond the building line. The free ends are then very elaborately and intricately carved. In addition, the walls are usually more or less artistically decorated. The carved ends of the joists strikingly resemble the elaborate carvings on the vintas of the Samals of the Sulu Archipelago, and are unquestionably a survival from ancient seafaring days.

The Marinao excel in brass work, some

of their betel boxes, inlaid with silver, food containers and ornamental vessels being of very unusual design and possessing real artistic merit. Agongs, as they call brass gongs, are of various sizes and are a form of portable wealth much esteemed. Old agongs of historic or legendary fame are valued at extraordinary and utterly unreasonable prices. Many of them are very sweet toned. Agongs have a therapeutic value, according to the Marinao; when a person is sick the agongs are beaten to drive away the devils that cause the illness. If they are sounded long enough the patient either gets well or dies. If the former, it was due to the virtue of the agongs, but if the latter it was because the devil was too powerful.

Marinao women are expert in making mats, of handsome and distinctive patterns and colors. These mats are used for beds. They are also skilled weavers and from their crude looms come very handsome cloths of mixed silk and abaca. Their malongs, as they call the East Indian sarong, and head cloths are not only strong but brilliantly beautiful as well. A Marinao dandy in full regalia is an imposing sight, with his bright flowing garments and wide, silver-mounted hat. The carrying of kampilans, as the great two-handed native sword is called, krisses and death-dealing spears is now contraband, and the Marinao men are no longer picturesque walking arsenals.

But hidden away in Marinao homes are still many, many blade weapons. In 1925 Mr. C. O. Douglas, supervising principal at Lumbatan, and I went with Lieutenant Diokino of the constabulary to see what we could do to avert a battle between two rival factions who were at war over the sultanate of Masiu, a position not yet vacant, for the sultan was still alive, though very old. The two groups, each numbering about 190 men, assembled at the southeast corner of the lake soon after daylight. The defenders of the existing régime gathered about the great house of their datu, shown in the picture. Those clamoring for a new deal swarmed in and about a cota, or native fort, about half a kilometer away.

For over three hours fighting threatened to start any moment. The first kris brandished would have been the signal to cut down the meddlesome peacemakers. Had we been armed or shown alarm we would have been cut down at once. About 10:30 our reinforcements arrived, 25 raw constabulary recruits, trembling with fear, but in charge of four seasoned sergeants and corporals. The tension eased somewhat then, but it was 2 o'clock before the warring factions withdrew simultaneously.

It was a great experience, for there was displayed the most wonderful aggregation of blade weapons imaginable. Every man carried a kris and most of them had kampilans and daggers as well. They had not only the characteristic Lanao-made kris and kampilan, but weapons from every part of the Malay world and the route to Mecca—heirlooms and weapons famed in Lanao song and legend, many generations old, and weapons that were part of the loot of piratical raids from Pinang to the Aru Islands; weapons with carved ivory or elaborate golden hilts, blades inlaid with silver or encrusted with gold, weapons that would make the heart of a collector ache with envy; even the poorest were silver mounted. Most of the men also carried silver-mounted spears with tremendous razor-edged blades and shafts of palma brava, every one a museum specimen. In addition each side could also muster about forty guns and revolvers of almost every make, all strictly contraband and most of them of no value, except as curios.

The social organization of the Marinao people is amazingly like that of our own ancestors some generations removed. A hair-trigger, clannish people, dirty, ignorant, but of keen intelligence withal,

hospitable but suspicious of outsiders, they have the faults and also the virtues of a Gaelic clansman.

A wealthy datu in his great house lives like a minor feudal lord. His wives, children and immediate retainers, whether freemen or slaves, live with him and make up his little circle. Life is a curious mixture of despotic authority and the most democratic freedom, but that is true of practically all Mohammedan communities. The datu is bound to protect his retainers and give them food and shelter if needed In return they till his land, do his bidding and follow him to death if need be

The Marinao respect a good fighter and will acknowledge the supremacy of the leader who defeats them in battle and then treats them exactly as promised. But they are ever ready to take advantage of those who vacillate and will go to any extreme to revenge themselves upon those who evade or break a promise.

Our ideas of Mohammedanism, with the veiling of women and their seclusion in the harem, are derived from Turkish or Arabic sources. Like all wide-spread religions, Mohammedanism has adapted itself to the customs of the country. The veiling of women in India, the Near East and northern Africa preceded Mohammedanism and is a heritage from the remote past. But amid the teeming millions of Malayan Mohammedans there has never been any veiling of women and little or no seclusion. The Marinao woman, therefore, takes her place in the community on a nearly equal footing with men, just as women of all creeds do all over the Philippines.

The characteristic structure of Marinao society is rapidly being destroyed. The great piratical datus of the south coast of Lanao vanished years ago, and the desperate fighters of Bayong have been vanquished, their cota, unconquered for a hundred and fifty years, captured and dismantled.

Twenty-five years ago the Visayan sakayan that ventured too near the coast of Iligan Bay was captured and its unlucky crew killed or made captive. A few years ago there was not a house on the coast between Iligan and Kolambugan. To-day coconut plantations reach more than half way from Iligan to the great lumber camp of Kolambugan, and the region is no longer a place of dread. The lumber camp has been a potent factor in effecting change, too, since about half its horde of workers are Marinao from the far-off hills remote from outside influences.

The automobile road now extends along the west side of the lake, and a dirt road extends on to Lake Dapao. It is only a matter of a very few years until there is a good automobile road all the way down to Malabang on the shore of Illana Bay. A good road means that the outlaw and cattle lifter can no longer raid with impunity and then escape to his hills. (How like the whole thing is to the cattle raids our Scottish ancestors pulled off "Across the Border.") A good road also means that the Marinao will travel about more readily, be reached more fully by outside influences and will respond to changes in the great world beyond Lanao with comparative rapidity.

A few years more and the Marinao will become standardized in the regular Filipino pattern, or else be exterminated. There should be a happy compromise between the two which would ensure them their full development. No matter what happens, studies should be begun of them right now, before it is too late.

There is still a fine opportunity for the exploring botanist to add materially to our knowledge of Philippine plants and their distribution by exploring the slopes of the Butig range. The rich insect fauna is practically untouched, and little is known of the other invertebrate life of the region, whether aquatic, terrestrial or arboreal. Even the birds and

reptiles have not been carefully studied, while as stated before the fishes of Lake Lanao offer a field for the investigation of certain aspects of evolution that is probably not equalled by any other locality yet explored.

Life for the naturalist should be pleasant at Camp Keithley or any other place where he might establish his base in Lanao. His work would inevitably assume the aspect of a delightful vacation amid beautiful surroundings. If it did not also assume the purple and rose of romance it would merely be because he had mistaken his vocation. It would be inexpensive, too, for a little money goes a long way in Lanao. Americans, Christian Filipinos and Marinaos alike would cooperate with him in his explorations. To the naturalist who desires to take up a practically virgin field amid surroundings entirely different from anything he has ever encountered before, and which have a many-sided appeal, I can not wish for anything better than a few months in Lanao.

PELE'S MOODS!

By Dr. G. R. WIELAND
DEPARTMENT OF PALEOBOTANY, YALE UNIVERSITY

In Ferdinand V. Hayden's U. S. Geological Survey Report for 1872, geologist F. H. Bradley notes overhead sounds about the Yellowstone Lake—not reaching musical pitch, however. Nextly these sounds, shortly after described as resonant or metallic rather than musical, were frequently heard about the Yellowstone country in July–August, 1890, by Professor Edwin Linton, then of Washington and Jefferson College, Pennsylvania, and Stephen A. Forbes, of the State Natural History Survey of Illinois, Urbana. Linton and Forbes were then making a biologic survey of the park waters for the U. S. Fish Commission, and both shortly recorded their very unusual experience. Forbes' note on the sounds was given in the *Bulletin* of the U. S. Fish Commission for 1891, published April 29, 1893, while Linton gave an interesting account of the phenomenon in *Science* of November 3, 1893 (pp. 244–6).

From that time on the marvelous aerial acoustics of the Yellowstone get singularly scant note for years. Even the guide-books, gotten out with all that avid, arid thirst for the ultra-wonderful, are silent! Except that in General Chittenden's "Yellowstone National Park" (pub. Cincinnati, 1915), the "acoustic phenomena" are given direct mention.

On July 30, 1919, Hugh M. Smith, then at the head of the U. S. Fish Commission, heard the rare sounds while fishing from a canoe near the outlet of the Shoshone Lake at its southern end. He noted that the sounds seemed augmented when the canoe motion was quickened and the line held by a bamboo rod became taut. Apparently in still water the curved sides and bottom of the canoe acted as a sort of sounding board, tending to focus the overhead sounds. But the description of the sounds later given in *Science* (June 11, 1926, pp. 586–7) varies from earlier accounts. The sounds are now noted as "musical, of rare sweetness, rich timbre, and a full volume increased by the noiseless surroundings." So great was the astonishment that "one was all but prepared to see a pipe organ suspended in midair." Duration was from ten to fifteen seconds, and was later thought to range in pitch from below center C to even above tenor C of the pianoforte, the tones "blending in the most perfect chromatic scale."

Nextly, in *Science* (July 30, 1926, pp. 586–7) Forbes, noting Smith's communication, again briefly mentions the sounds as he and Linton heard them on the Shoshone Lake and at the Yellowstone Lake in 1890. He too is surprised that so little note or attempt at explanation has been given the sounds; Linton comes back to the subject in *Science* (January 24, 1930, vol. lxxi, pp 97–9) quoting his original notes of 1890. The sounds were then heard July 23, August 4, 8 and 9, being first noted at the upper (western) end of the Shoshone Lake by boat about 8 A. M. Heard best, the sounds rather indefinitely reverberate in the sky with a slight metallic resonance; or again they are like a mixture of sounds as of wind in trees, telegraph wires, echoing bells or humming of bees, etc.—all making an easily recognized sound which would be easily overlooked where there were many noises. Forbes notes too that ranger naturalists record the phenomenon from Grebe Lake, near the cañon of the Yellowstone, and that in the "Ranger Naturalist Manual" for 1928 a summary is given by Ranger Marguerite Arnold. And with these forewords may I now record a personal experience of thirty-two years ago?

On September 8, 1902, walking through the pines alone by direction, and the day being clear and still, I reached the western shore of the Shoshone Lake. As I strolled down over the sinter slopes of the Geyser Basin, and amongst the hot water kettles near the lake edge about 11 o'clock of the morning with quite enough of self-sufficiency and vanity perhaps, a sudden burst of intensely musical sound swelled for some seconds through the air above me and as if somewhat out over the Lake, rolling away to be lost in the distance. The effect was absolutely startling. Nothing in my young life had ever prepared me for anything quite like that! At first I thought of some camp unnoted and sounds like some great accordion or Jew's-harp, or bagpipe. But only gnarled trees were in sight, and the cadence had distinctly seemed to proceed from some moving source overhead, gaining in volume as it neared, and fading away in the distance. Then followed an awareness that the sounds had lasted long enough to bring a futile response as if to avoid or evade them or have them stop! Next there was some sort of inadmission of fear and dare to the inexplicable. A mindedness that was set, and "from Missouri!"

The manner in which the sounds changed as their source seemed to move easterly was striking in the extreme Linton especially notes the break of more musical notes as heard about the Shoshone into reverberations or explosive noises usually passing to the southwest; and he thinks he may by chance be mistaken in a note recording disappearance easterly. I also heard curious reverberations and little explosions following the musical tones. These seemed to continue for some seconds off to the east, as if moving along the shore out of sight from one to two miles away. The effect was odd, not quite like the sound of fire arms, nor yet of thunder, and it seemed too uneven, too little located to have come from any camp. It made the musical sounds even more mysterious. The reverberations seemed to pass far out over the lake. Thinking back, taking the rate at which sound travels into consideration, it would seem possible that although the musical cadence was heard first it might or might not have been preceded by the explosive phase. On following days, about the Heart Lake Geyser Basin and in climbing Mount Sheridan, I noted no further sounds.

My purpose in scouting round the outlying hot springs and geyser basins was to observe firsthand any evidence for initial stages of petrifaction, or cellulose replacement by silica or calcium carbonate. The notes then made have held high interest ever since. It was seen

that there was considerable infiltration going on as woody materials slowly disappeared. Pine needles found in the hot water kettles at the Thumb of the Yellowstone Lake seemed completely replaced But the general impression gained was that the conditions favoring more perfect types of replacement, were mostly hidden from view, where heat and some pressure might aid in the breaking down of cellulose by orthosilicic acid. Some minor laboratory experiments recently made confirm the impression that cellulose is very resistant to change, even in the presence of silicic acid. But undoubtedly the optimum conditions for opalization can be determined in a course of simple experiment

It is much to admit; but I can't recall that I even mentioned those sounds or more than vaguely held them in mind, until I read my friend Dr. Smith's account and learned for the first time how slow might be my own response to what was outside all ordinary experience. No less, I had yet to learn something further of the psychology of utter surprise and of ignorance By chance I chose a wooded valley set in the hills near the Little Sebago Lake in Maine to await the total solar eclipse, August 31, 1932. Obliquely opposite lay a long rising lateral thick-wooded swale. This, as it turned out, was set just right for the writhing play of colors often noted as an eclipse begins or ends The scene was picturesque in the extreme. There were heavy clouds near, and there was just enough of a haze to ruin the outer corona, the inner, however, showing fairly bright. Just as a great Bailey bead flashed out and the shadows rushed on, that swale seemed a swaying, tempest-torn, moving Birnam wood. Such was the singular effect of the color play. Having seen the colors in very different light on the snow (eclipse of January 24, 1925) did not help. Once more there was an instant of intense surprise, though it thus became evident that the eye (as before the ear) had really caught the extraordinary. For once more the sudden, uncontrolled secondary reflex, even defining fear, asked cessation! Only this time all was set in memory.

From Marco Polo's singing sands down, aerial sights and sounds have surprised and caught unaware all humans. They have led to superstition and to poetry. Thus in *Science* a fine essay on the musical sounds has been given by Professor Henderson of Yale (September 26, 1924, pp. 282–83). And one might well recall some of the imagery of the German poet Uhland.

> Man horet oft im fernen Wald
> Von obenher ein dumpfes Läuten
> Doch niemand weiss von wann es hallt,
> Und kaum die Sage kann es deuten

Evidently there may be more of the remoter natural sounds by far than the texts admit. One might speak of the *near* sounds, or echoes, and the *far* sounds or those of more recondite source. Multitudinous sounds may approach the musical, though the ordinary sounds of the hills or mountain sides are dissonant. Consonance, with vibratory volume being mainly physical or mathematic, must be a rare phenomenon—one so outside knowledge that it would be missed entirely amongst the sounds of ordinary life and fields. The primitive man hears the sounds, sees the sights of the lonely places and peoples the air. Thus the intelligent Hawaiian lady at the Bishop Museum has told me something of Pele. About Halemaumau, the name meaning, "the fern house," she dwelt. In anger she rose above the storm, the lavas flowed, and the fern forests were a sacrifice to her; though they soon grew forth again.

Quite the most extraordinary of all nature sounds accompany the Aurora. And as these sounds would have a physico-chemic cause, and come in the sun-spot cycles, day or night, the question might well be raised whether the sounds of the Yellowstone are in part or in any sense also cyclic and coincident or connected. The sounds of the Yellowstone, as reported, or as heard just locally, do not seem as continuous as the auroral sounds of the high North.

But there is certainly a degree of similarity. The question is whether auroral sounds may also reach musical cadence.

In *Science*, for September 8, 1933, Clark M Garber relates his experience while crossing the mountain range bordering the Arctic coast north of Cape Prince of Wales on the Bering Strait, during a fine aurora of the winter of 1925–1926 At midnight, as the display took on the drapery effect, audible sounds like "crackling from fine jets of steam" continued for some time This I must believe exactly correct; though, as it chances, it is the first time I have ever heard the subject broached, or noted it on printed page. Reading for a general description, I find I missed all paragraphs on auroral sounds!

As usually stated, the audible aurora is not heard in our latitudes. About eight o'clock on the evening of March 22, 1920, a telephone call from a near neighbor advised me at my home near the Oyster River, Connecticut, that what shortly proved to be the greatest auroral display of our neighborhood for this century was on. I rushed back into our meadow as the great draperies, yellowish rather than of other or high color, were sweeping close before from out of the north. The drapery or curtain form was sublime, amazingly close. From within it there welled out a very distinct volume of sound, perhaps like some close-by shower or fine threading sizzling rain. Or taking that simile further. From the Chuska front on the western edge of the San Juan basin I have sometimes watched a thousand feet through of rain storm in the making. If all those swaying sheets of rain had been masses of infinitesimal threads emitting a thin, boiling wave of sound there would have been simulated somewhat the auroral sounds I heard while getting into position for more carefully noting an amazing moment. But just then the draperies seemed to dissolve into a second phase which I watched from the roof of my house far past midnight, as a silent display of threading light and oriented cloud effect.

As Professor Schlesinger, of Yale, has explained to me just now, the "rustling silk" sound attributed to the aurora of the high north must be very similar to what I heard, as also to some of the sounds described from the Yellowstone. And the neighbor, Mr. Joseph H Roseberry, who telephoned, now says he and his son Hugh believed they too heard a sound, much as I did. So far, however, it is not understood that such sounds are musical, as Dr. Smith (quoted above) heard them at the Shoshone Lake, and as I heard them there in quite the same tenor.

Strange, strange, as before in the Yellowstone eighteen years earlier I discounted my impressions as merely the impossible. But I am not wrong, and just as I now at last learn that the Eskimo hear the aurora, so I am sure that yet others may recall that in our latitude where brilliant display is rare, they heard that of March 22, 1920. And if these sounds are of a physicochemic source, may not some of the sounds of the Yellowstone have a similar nature or even be partly auroral?

Recalling as above, Dr Smith heard the musical sounds at the outlet of the Shoshone Lake in almost identically the same manner as I did six miles due west at the Geyser basin; except that he noted the sounds firstly from his canoe, while I heard them ashore From this fact it may be inferred that the sounds often pervade the air, perhaps to a considerable height over the surface of the entire lake and its adjoining shores. Hence in the complete absence of synchronous observations at different points it is difficult to see how the primary explanation of the sounds as a purely vibrational effect due to deeper thermal or explosive

activity may be a sufficient one. Have the Yellowstone aerial vibrations on the contrary some chemic, or radioactive source? May one imagine some form of interception of rays from without as a cause of areal atmospheric sound—sound occurring over large areas in a highly characteristic tone?

Certainly the auroral sounds scarcely come from the high altitudes of fifty or sixty miles where the visible effects appear. In any case here is a significant series of facts about which next to nothing quantitive is yet known. Slowness of observation is much due to the near impossibility, in all casual notation, of recognizing true aerial sounds in any but the lonesome spots of earth—those of the high altitudes or within the arctic areas.

Since the preparation of the foregoing notes there has just appeared in *Nature* (December 2, 1933, p. 385), a short account of auroral audibility, and the "low Aurora" by Messrs Davies and Currie of the Canadian Meteorological Office, Toronto. They give the experiences of the Canadian Polar party near Chesterfield Inlet on the west shore of Hudson Bay. The testimony of Esquimaux and others is very variable; but both whites and Esquimaux probably hear low swishing sounds which are auroral, not subjective. Maximum audibility is in the region of maximum auroral frequency.

That there is indicated some form of audible ray reception, or atmospheric ionization effect, or even both combined, must be held true of the Aurora. It is evident too, that there is dissimilarity between the *low* and the *high* Aurora. While the phenomena of the former certainly invite comparison with what may occur in a region as active physico-chemically as is the Yellowstone.

Notes on sound phases of volcanism, especially those precedent to renewed activity, mostly lack a comparative form. Could such be transmitted by radio, or given more exact record? But these sounds much resemble those heard about the Yellowstone in more subdued tenor. The burr of the Castle geyser before play is cited, and the merely general comparison I may make. In May, 1907, the year before the destruction of Messina, I climbed the ash cone of Etna in the darkness of early morning, reaching the summit before sunrise. Midwinter conditions as it seemed yet held, and the inner edge of the crater could only be seen in patches as strong winds momentarily tore away the thick curtain of mist and solfatara gases. Climbing to the edge of the cone meant taking a little of chance, and one could only remain there for a minute at a time, owing to difficulty in breathing. The mountain was well understood to be growing active. A tremendous resounding burr of component sound rose from the crater depths.

INTELLIGENT PLAN IN NATURE, EVIDENCE FROM ANIMALS[1]

By Dr. MAYNARD M. METCALF

Is there evidence of intelligent plan in nature, or is all due either to chance, or to purely mechanical outworking of relations in the primordial substance or force or whatever it is that is the ultimate existence? This question is, of course, one of interpretation and not to be answered by scientific description.

There is much in nature which suggests design. Apparently from very early times men have so interpreted isolated natural phenomena. At first they saw "spirits" in all the natural world, spirits at least mildly malevolent, if not violently so. Men's constant thought was of propitiating the spirits in earth and air and water, in sun and moon and stars, in trees and rocks and mountains, in beasts and birds and fish, in storm and lightning and earthquake. Nothing happened by chance or by mechanism; everything was purposeful, however capricious the purpose. The universe, as men knew it, was peopled by a multitude of demons, little demons, big demons, petty mischievous demons, fearful devastating devils, and all conscious of man, whose chief concern was to propitiate them so that at least they might leave him alone.

In time good spirits were added to the devils, and angels fought with evil demons. But still man had no thought of any comprehensively consistent relations underlying the seemingly capricious phenomena about him. This conception has evolved slowly with the progress of science, and is yet to many minds not clearly defined. The Greeks and Romans, the Chinese and the inhabitants of India, the Mesopotamians and Persians and Egyptians, all thought of nature as controlled by gods without any unified purpose. Even "monotheism," with its good god in control of his angels, and more powerful than the bad god with his devils, hardly brought men's philosophy of nature to the point of belief in harmonious unity. Daimonology still ruled the common man. Gods, angels, devils and saints constantly influenced men's welfare. Until rather recent times all men have believed, and without question, in purposeful control of natural phenomena.

But, especially during the twentieth century, there grew a new school of thought, which rejects intelligent plan and purposeful action in nature. In its extreme form, a group in this movement rejects, even for man himself, the reality of intelligence or purpose, all this sort of thing being unreal and delusion. This philosophy recognizes unity in nature, but no intelligence or design. Unintelligent mechanism, on the one hand, and capricious, daimonic control, on the other, are the two extremes. Both extremes seem beyond acceptance. What middle ground can the ordinary man find on which to found his life? What view of the universe in which he lives may he take?

We have set ourselves a difficult question, but not one which is beyond profitable study. Let us approach it in the scientific spirit, rejecting no class of natural phenomena, physical or spiritual, which are capable of being tested and so are within the scope of scientific treatment. We will limit the inquiry to data furnished by animals.

[1] A chapter from an unpublished symposium volume upon intelligent plan in nature, written by thirteen men of science in England, Scotland, Germany, Canada and the United States.

Many persons limit the word scientific to physical phenomena and relations, denying that spiritual (*i.e.*, personal) phenomena can be tested by the scientific method. I believe, on the contrary, that spiritual phenomena are as capable of scientific testing as are physical phenomena. The method is the same for both kinds of data, although the criteria of reference, of measurement, in the two are very different.

What is the scientific method? It is observation, hypothesis, deduction and experimental testing. The student of physical science observes certain phenomena, perhaps unfamiliar phenomena, and after repeated observation and careful thought upon them and upon known phenomena which seem to be related to them, he forms an hypothesis which seems to be consistent with all the known data. He then ruminates over the hypothesis to see what necessary implications it may have Then he tests the validity of the hypothesis by testing one or more of these necessary corollaries, if he can devise satisfactory experiments for this purpose. If he can not find a way to put the hypothesis, or some of its necessary corollaries, to experimental test, he realizes that the hypothesis is unproven and must be classed as speculation until satisfactory indication of its validity shall appear

The student of spiritual, personal, phenomena uses identically the same methods. The only difference between the students in the two fields is in their criteria of reference, the measurements they use The physicist uses grams, meters and seconds. The student of spiritual phenomena uses the test of harmony with nature, as shown by the increased spiritual power which results from following spiritual hypotheses that are in harmony with the Whole, or the diminished power which results from disharmony. The tests in the two realms are equal in validity, but those in the personal field require more time to get the readings, for they are a matter dependent upon growth

If we observe animate nature in its broader relations, one of the things which most impress us is the adaptation of plants and animals for the lives they live in the midst of their surroundings. A fish, with its stream-lined form, its posterior propeller, its lateral oars, its nose and eyes at the anterior end of the body where they give notice of what the fish is approaching, its swim-bladder to counterbalance its weight, its gills for water-breathing, and, in fact, all its organization, shows adaptation and shows peculiar fitness for life in the water. A bird shows even more striking adaptations, especially those which enable it to fly. Its air sacs and its hollow bones filled with warm gas give it buoyancy. Its wonderfully constructed and interlocked feathers are, even in minute details, peculiarly adapted for flight. Thousands of sorts of insects and mollusks and worms show adaptations which fit them for the lives they live. The one-celled animals, even those so small as to be almost invisible, show equally detailed and remarkable adaptations. Adaptation, fitness for the lives they live, is a well-nigh universal character of living things and is shown in many of the minutest details of their structure and of the most intimate features of their physiology and behavior.

It is true also that the adaptations change as the animals change from one kind of life to another. Fish have swim-bladders which make them less heavy in the water, but they do not use them for breathing air, except that the lung-fishes, more highly evolved forms, do swallow air into their bladders and use it to assist slightly in aerating the blood. The frogs start life as fish-like tadpoles in the water and breathe by means of gills like a fish Later, at the time of metamorphosis to adult frogs, they leave the water and become terrestrial; at this time the organ which in the fishes was a swim-bladder develops into a true lung with its very thin walls richly supplied with blood-vessels. Higher vertebrates, which have no aquatic life, pass beyond the condition which is adapted for life in the water while they are still in the embryo stage and they have functional lungs from the beginning of their active lives. The same organ, differently developed in different animals, is thus first a swim-bladder and later a pair of lungs, but in each condition it is adapted for the use to which it is put.

This principle of change in adaptation is illustrated in probably every

organ in the higher animals. In man, for example, I can think of no organ which was not once in a different condition and adapted to serve an at least somewhat different purpose. The mammalian heart began, as in a lowly relative of the vertebrates, Amphioxus, where it is a mere tube which contracts in waves from behind forward and so pushes the blood along. In fishes the walls of the tube thickened and developed chambers separated by one-way valves, making it a more efficient organ for propulsion of blood But still in these gill-breathers all the blood takes but one course, going first to the gills to be aerated and then to the body to carry oxygen to it, allowing the cells to breathe In air-breathing vertebrates, which get their oxygen through lungs, the heart and its connected blood-vessels are completely divided to form two streams, one connected with the comparatively feeble right half of the heart, which propels the blood merely to the lungs and back to the heart. Returning this time to the heart, the blood enters the much stronger left side, which pushes the aerated blood along a much longer course to all parts of the body, except the lungs, and back to the heart, ready to start again to the lungs But in all the stages of the evolution of the heart, from the straight tube in the ancestors, through the undivided heart of the gill-breathers, on to the double heart of the lung-breathers, the structure has been sufficiently adapted to the needs of each organism to serve it effectively.

One of the most noteworthy series of changing adaptation in a single set of organs is that which has given us our organs of smell, taste, balance and hearing. Beginning as pointed cells scattered irregularly over the skin, as in Amphioxus, they have developed into the grouped sensory cells of all the organs named, and probably also into feathers and hairs. Adaptation, growing more perfect and more diversified, characterizes evolution throughout.

Not only adaptation and change in adaptation, but, even more, parallelism in adaptations, are impressive, and such parallelism is, perhaps, especially significant. The marsupial mammals, the group to which the opossums and the kangaroos belong, are not closely related to the other mammals, yet we find that they have used many similar adaptations to fit them for the lives they live There are, thus, wolf-like marsupials, rodent-like forms and others which resemble insect-eating higher mammals

But as conspicuous an example of parallel evolution as we could well find is seen in the eyes of the highest mollusks, the cuttlefishes, and in those of the vertebrates. The eyes of the two are built upon the same mechanical plan, a firm-walled eyeball containing a retina with sensory cells and pigment, a partition across the eye separating an anterior from a posterior chamber (open to the exterior in the mollusk), a central opening in this partition and a lens in this opening, and several other remarkable detailed resemblances But the two eyes are fundamentally different. One develops from the skin of the head. The other arises in part from the skin, but chiefly as an outgrowth from the internal, nervous tube from which the brain and the spinal cord also arise. The retina in the vertebrate eye is inverted, with its sensory cells turned away from the light, turned inside out, as it were. But the molluscan retina is undistorted, its sensory cells being directed toward the light, as is, of course, the natural arrangement.

The cuttlefishes are no relatives of the vertebrates. The eyes of the two are wholly unrelated, and in both embryonic development and in evolution their eyes have followed wholly different routes, but they reach a final result which is the same in the remarkable, elaborate, me-

chanical adaptations by means of which these eyes function. The keenest imagination is wholly unable to follow the course of the evolution of an organ so intricate as the eye of man. It seems almost beyond belief. But for two eyes, in unrelated organisms, to start in different portions of the body and, by very different series of changes, to reach a structure fundamentally the same functionally, even in great detail, yet wholly different morphologically, is fairly flabbergasting. The wildest imagination could not invent such things. One stands dumfounded in the presence of such phenomena.

This all surely suggests plan, purpose,[2] in nature. But, if so, it is not a single, stereotyped plan and a limited purpose. Charles Kingsley, in that delightful book "Water Babies," makes the good fairy, Mother Cary, say "Know, silly child, that any one can make things, if they take time and trouble enough; but it is not every one who, like me, can make things make themselves." And this may be the key to the infinite diversities of adaptation in nature, there being as many artists engaged in designing adaptations as there are living things to share in the use of them. All animals and plants are engaged in fitting themselves better and better for the places in which they live and the very diverse things they have to do. Mother Cary's method of having each work at the designing, so that there are as many artist-artisans as there are individuals, is infinitely clever and makes coworkers of them all.

Of course, not all individuals, nor all kinds of animals, are well adapted; and the ill-adapted perish in the end. Not only is this true; there are even strong trends in some animals toward evolution in disadvantageous directions. Many species, genera, families and larger groups of animals have become extinct because of such obstinate insistence upon developing into increasingly ill-adapted structure and physiological habit. Examples are the huge, prehistoric reptiles, who kept on evolving great bulk until their alimentary canals could no longer feed them, bulk increasing in cubical dimension, while the digestive and especially the absorptive lining of the alimentary tube, which prepares and gives them all their food, increases chiefly in surface dimension and is ultimately swamped by the impossible task placed upon it by the great body.

No intelligence in animals themselves saves them from destruction. If they keep within the limits of serviceable adaptation, it is through an automatic self-regulation, and our question is whether this masterful self-regulating system in nature is due to Mother Cary's wisdom or to chance. It is not only animate nature we must consider, but inanimate nature as well and the way the two interact.

Recent concepts of the universe seem to be reducing it all to force. Matter, substance, according to those who hold these views, is as outworn an idea as is that of a world of indifferent or malevolent demons. A bit of matter, a stone, for example, is conceived as a congeries of discrete, though not unrelated exercisements of force. We think that a stone is not solid, but that there are spaces between its atoms, and spaces between the electrons and protons, the atomic nucleus and the possibly considerable variety of entities within the atom; and there is even lurking suspicion in many minds that the atomic nucleus itself may prove to be a little universe of great complexity. At any rate, we conceive a stone as containing much more of empty space than of substance. And all which we might possibly think of as substantial, the protons,

[2] Purpose seems too limited a word. It is the fundamental organization and character of the universe itself, without which the universe could not exist, which is intended in the word, the trend, the direction of all existence in its most fundamental aspect.

electrons, neutrons, atomic nucleus, etc., are themselves, in this type of thought, resolved into bits of force.

Thus our universe, as we at present conceive it, seems to be resolved into force present as discrete exercisements whose salient features are not all quantitative (space and time relations), so far as we can judge, but are in part qualitative (electrically positive or negative).

If, therefore, force[3] be all, however complex and diverse its manifestations, whether as rock or plant or human being, our question with which we started seems to be, "Is the force, which is all there is, itself intelligent and purposeful, or is it controlled by something other than itself which is intelligent and purposeful in its exercising of control, or is it all blind, mechanical, with nothing of intelligence or purpose?" I can give only my own feeling as to this question and some of the reasoning which leads me to the conclusion which has been for me the acceptable one.

I find no evidence in favor of conceiving of two distinct entities, a force which is the universe, and something besides the universe, which controls the universal force; though such conception would not affect our search for intelligent plan in it all. I have no quarrel with the man who prefers the dualistic conception. The indications of intelligent purpose are the same in each case. But to me the universe itself is either intelligent or unintelligent, purposeful or lacking in purpose, personal or mechanical, just as a man is intelligent, purposeful and a person, or is lacking in these qualities. Is the universe a person, God, if you will, or not? Man is no less a person (if he be a person, *i.e.*, not an automaton) because he has a physical body which can not be called personal either in its several parts or as a whole.

Our question, "Is nature personal?", which is essentially the same as "Is there intelligence and purpose in nature?", suggests that we look into the matter and see if we find intelligence and purpose. As we have said, the wonderful and well-nigh infinitely diversified adaptation seen in nature might well suggest plan. And the fact that we find in living nature a method of self-regulation, which brings about adaptation, does not necessarily halt our further search by relegating all to mechanism. Let us look further.

In nature itself we find, beyond all question, as it seems to me, purpose, force, personality. Man is a part of nature, and man possesses intelligence. His acts we directly know to be sometimes purposeful; and we know directly that we exercise power toward the attainment of our purposes. We have direct knowledge, in ourselves, that man is thus a person, a person with capacity for appreciating beauty, goodness, honor, faith, faithfulness, all of which are aspects of beauty, and he is capable of feeling the urge, the compulsion of beauty. Intellect, sensitiveness to qualities, as well as sensitivity to quantitative stimuli, power to choose and power to endeavor in the line of his choice—a person.

If such a bit of nature, built up by nature in her growth, has the inexpressibly great and valuable qualities inherent in personality, can it be otherwise with nature herself? Can the part be infinitely greater, qualitatively, than the whole? To me the very asking of the question is its answer. Of course nature, which made man and comprehends man, is no less worthy, is no less beautiful than man and his possibilities.

Man is able to reveal himself to other beings who have souls and so can appreciate man's personal revelation. Similarly, nature can reveal her soul, God can reveal his personality, to other beings who have souls to receive the revelation. The extent of the possible

[3] Note that force, not energy, is the word used.

revelation is measured by the breadth and the depth of the recipient. This is the confession of faith of a humble follower of science, to whom the endeavor to view all phenomena honestly has indelibly impressed the spiritual phenomena of personality, the overwhelming importance of the personal. To me the spiritual is primary, the physical derivative from the spiritual, not only in worth and purpose, but also factually in causation. I have felt my will acting on my body, and through my body producing physical effects. This causation is more than antecedent and consequent. It is real, vital, personal, in myself, and it is effective force With the ever-present urge toward unifying underlying relations, I cannot but feel that the physical and spiritual are essentially one and that the spiritual aspect is primary, the physical its outworking; in other words, that God's will sustains everything and that all is directed by intelligence and is purposeful. And this conception of the universe as intelligent force I get from animals, especially from that animal which I am

The only idea we have of essential causation, an antecedent containing compulsion so that the result has to follow, comes from the fact of our wills exercising such compulsion. To be sure, our will may be successfully opposed; but the fact of the compulsion we know, and its at least occasional success in producing effective result we observe, and it is from this attempt to produce result, an attempt we directly feel in ourselves, that the whole concept of cause comes. Our volitional act may be, as it were, a catalyzing agent, releasing energy stored outside itself. The measurable energy of any resultant activity is not the same as the volition, but in the volition is found the instigator of the series of physical phenomena which follow. And there may be, of course, a train of spiritual results following our volitional act, which are no more measurable by physical measurements than is the act of will itself. Without this experience of volitional urge and the resultant phenomena, all our thinking would be in terms of mere sequence. The whole concept of force would then be absent. It would never have entered our minds to construct the idea of cause, if we had not had experience of cause inside ourselves, experience of force, of effective force; and this force which we experience is our own, is personal.

That this animal which I am has the capacity to comprehend the whole in its plan and purpose is, of course, unthinkable; still there is one more question arising, which will not down—"If purposeful, what is the purpose? If nature has a trend in its fundamental being, what is the direction of that trend?" Hopeless as any adequate answer is, still one can not refrain from dreaming What we may find of purpose is doubtless but faint adumbration of the breadth of the whole, but, if we are made in God's image, that is, are consistent products of nature herself, our concepts, though infinitely limited, may not be utterly false. To me, and I can not speak for any other, creation, growth, and, as the highest I can conceive, growth of beauty, and especially of that beauty which inheres in persons, is the most restful, most satisfying aspect I can conceive of what may be nature's purpose. Growth is one of the most fundamental characteristics of living things, possibly the most fundamental. If nature be alive, if God is alive, apparently there must be growth, and growth including its culmination in spiritual beauty.

Thus in animals, in man, we find the evidence of intelligence and purpose in nature, and in our sense of beauty, in the dominant, controlling influence of beauty upon our spirits, we find a suggestion of an apparently sufficiently great purpose for nature, the purpose of the exercise and growth of that person who is nature and of creating[4] persons

[4] By evolution.

who shall be centers of growing beauty[5] I was asked to discuss the evidence of intelligent plan in nature, as found among animals, doubtless for the reason that I have been a student of animals. I have, however, confessed the inadequacy of such evidence if man is not taken into the picture. But man is in the picture, very much in the picture, and man is an animal, a product of nature In him, just as truly as in an amoeba, or a rock, or a star, she reveals herself; and man, as a person, with his intelligence and his capacity for purposeful action, is a part of nature's self-revelation. The question put to me to discuss is philosophical, but it is natural as well. Man is natural. I do not believe there is validity in any essential distinction between natural and supernatural. Man's capacity to appreciate beauty and duty is as natural as any other part of him. His capacity for experience of natural religion, for appreciation of the beautiful, for following the urge toward the beautiful, for recognizing the consequent duty to seek the beautiful, including beauty of conduct, his capacity for moral conduct, all are natural and, as such, are to nature means of self-revelation. The best in nature is as natural as are her physical aspects, and, as I see nature, her spiritual (personal) aspects are those which reveal her most intimately, tell of her purpose, make legitimate the search for answer to the question "Why?" as well as to the question "How?" Man himself is why, so far as he goes. What further reasons there may be we can not say But we may imagine that the why includes other sorts of personalities, and even nature herself, a great, self-revealing person. In the very nature of the case *we* must find the why in personality and in the values which only persons can appreciate If there be other whys they apparently can not appear to us as men. At least nature's plan includes, comprehends the personal.

Survey the whole sweep of evolution, the wonder of regulation amid the immensities of the universe, beyond the reach of the most powerful telescope; the equal wonder of regulation amid the minutae of atomic structure, far beyond the penetration of the microscope; the emergence of life on the earth, that speck of the universe of which we know most; the gradual development of intelligence, of reason, of appreciation of beauty and of power to create beauty, even the transcendent beauty of personal character. A star is no greater than a violet; gravitation is a force that can not transcend love. But it is all one, beginning in the dust and reaching up into persons who can appreciate and create beauty, a constantly changing whole. And it doth not yet appear what there shall be.

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[5] "To my thought, my experience and my observation of nature suggest, as the most probable guess I can make, that nature has its origin in intelligence, in love of the beautiful and in purpose, that is, in personality. The evidence for this, as I see it, seems to me to establish a very strong probability that this hypothesis corresponds to reality, and so I live with the thought of its probability steadily in my consciousness. I can not make it seem probable or real to me that nature simply came to be, or always was, as it is, merely by chance or without thought or plan or purpose. And I can not see that the fact that I can not, as yet at least, understand the origin of personality weakens in the least the evidence that person ality not my own does exist and is active in the universe. Science does not refuse to form any working hypothesis about its problem in hand, because it can not find an hypothesis that explains everything at once. It simply tackles its problems one by one, tests and modifies and develops them—all with the hope and with the experience that in this way progress may be made toward a larger vision of reality. Of course, if from my experience and observation I draw the induction that personality not my own exists and is active in the universe, and if this induction leads to contradictions or absurdities or increased rather than decreased difficulty in understanding nature, then my guess is worse than useless. But if it leads only to an unsolved mystery beyond, then it does only what all new insights into reality do for us. The larger the circle of our understanding, the wider the circumference at which we touch our unsolved mysteries." (From a letter by my brother, Wilmot V. Metcalf, to one of his pupils.)

WILD LIFE RESEARCH AS A PROFESSION

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THIS article is written for a purpose The purpose is to further ecological research on wild species, particularly vertebrates, the findings of which research may be of significance in the sane administration of natural resources. It is written for whatever value it may have for young people—let us say, those about to begin college—who want to enter or think they want to enter this field professionally.

I specify prospective college entrants because at this stage many sense the necessity of preparing themselves for a definite lifework, yet have only the haziest ideas as to what they will do for a living. Potentially strong man-power may drift into vocational blind alleys, to remain indefinitely as unproductive and unhappy misfits, often for little reason other than that at the time there seemed no alternative open to them. Of course, misfits can be as unfortunately situated in wild life research as in any other field, or perhaps more so; unless one is reasonably fitted for this sort of thing and wants to get into it chiefly for its own sake, he had best not turn too optimistically toward the field as a profession.

Wild life research is scientific in nature and must be sufficiently well done to hold together when subjected to scientific criticism. It demands mentalities equivalent to those demanded by other sciences. Although relatively mediocre minds may turn out excellent work through sheer effort, there is a limit to what effort alone can accomplish. And the field, though new and undermanned, is not devoid of competition.

Questions as to physique, personality, temperament requirements, etc., draw about the same variable answers that one would predict. The work itself may fall between all possible extremes, governed by what the investigator either wants to do or has to do, or both. The most effective procedure in ecological research seems one of alternate study of a species in a natural environment and under controlled conditions, that is, observation checked by experimentation. Field work frequently entails strenuous physical exertion or even hardship. Laboratory routine, correspondence, technical reading and writing, speaking and advisory duties may all receive a greater or less emphasis.

With respect to the matter of personal attitude, may it be said here that unless one is possessed of an enduring fascination for the out-of-doors, he is not apt to find wild life research much more than only a profession, one among a number for which he may be equally qualified. If this phase of ecology is really his field he should be responsive to the nameless appeal of the raw drama of living creatures as he is to little else; he should know the out-of-doors also as a refuge in which he may seek peace when tired, restless or discouraged. Otherwise, he may never feel that he receives returns commensurate with what he almost certainly will have to pay in one way or another.

Does the prospective worker understand what research is?

Research means the following of the truth, wherever it may lead, regardless of what may be the purpose of the research and the uses to which its findings may be put. If it is not conducted with intellectual honesty it is not research, irrespective of what it may be called. It is impartial and has nothing to prove or to disprove. It recognizes no precedences, no dogmas. It yields to no

authority save superior research. There is nothing mystic or awesome about it; its sole aim is to determine what is so.

Let one therefore make self-inquiry. Can he put aside personal opinions, personal desires, personal expediency, to make analyses on the basis of evidence? Many will be the times when he can expect his pet ideas to be punctured, his carefully thought out generalizations to disintegrate into confusion. He will find out things that do not please him in the least. He may be compelled to do things distasteful, if not revolting to him. Can he do what he has to and more? Can he be his own severest critic? Can he correct his mistakes when they are demonstrated and go on unashamed?

Can he keep his research truths intact in the face of pressure from outside groups with whose individual interests his findings might be at variance, but do so in a way to arouse no unnecessary antagonism? Ideally, research should be exempt from financial pinch, strife, intrigues, prejudices and jealousies, but it rarely is; as a human endeavor it can not be fully exempt from the ills common to human endeavors. A professional research career is not apart from life because it demands a detached perspective. The detached perspective has to be maintained despite the interplay of distractions, worries and crises which most of us have no chance of escaping.

There is something more, something not easy to put in words. Nor am I sure that I know what it is. I think it will be conservative to say that the roots of a real career extend farther back into a man's self than the depths at which he is dominated by such things as economic well-being, pride of achievement, and other more or less material considerations. A man must have more than ability, integrity and ambition. I believe that if he is to attain the heights he must be driven by a veritable passion, not only for his work but for what his work stands for. It must be more than a hobby or a livelihood or a passive pleasure; it must be the supreme interest of his life, for which he is willing to make endless sacrifices.

I may be wrong about this. I do not wish to say that a man with lesser interests could not make good or that his services might not be of great value to conservation. I suppose it is possible for a man to reach the top even though he were not fighting with all he had for something he loved. I suppose it is possible, but I don't see how he could for less incentive put in "that extra" which is so often mistaken for genius.

What should one have to start with before he seriously considers technical training for a profession of wild life research, aside from those qualifications requisite to any research career? What should be his general pre-university background?

Impossible it is, of course, to set up any arbitrary standards by which one's background could in fairness be judged. So much varies with the individual. Nor would it be much more than absurdity to say that research workers in the field of wild life management must arise from a given social stratum or from some other artificially circumscribed group.

An intimate familiarity with the out-of-doors prior to intensive formal training is of incalculable value to one working on ecological problems, though there are people who have demonstrated their ability to handle problems of this kind with scant previous experience. Persons naturally curious about wild creatures and who during youth have engaged in hunting, trapping, field hiking, scout activities and the like have a tremendous initial advantage over those to whom the out-of-doors is bewilderingly new. No one should overrate, however, the value of mere existence in the out-of-doors, for many may spend their entire lives in areas rich in woods and waters without

learning very much about even simple biological relationships.

Extremely profitable may be farm or biological experience and wide contacts with out-doors men of consequence—reliable "old timers," plant and animal ecologists and systematists, ornithologists, museum collectors, geologists, etc The more diverse the view-points with which one comes in touch the better, provided that one guards against forming opinions too hard-set to yield to contrary factual evidence

Relative to formal education, I am assuming that the prospective worker is ready to enroll at a college or university of good standing, and which makes available a regular four-year course in science leading to a Bachelor's degree. I am assuming that he has had in high school the usual prescribed English, history, algebra, geometry, physics, biology, as well as civics, sociology, and other orientation courses. A good reading knowledge of French or German acquired from high-school foreign language electives may be very convenient later on.

As a college underclassman, the student will probably be well occupied with prescribed work, regardless of the field of natural science in which he majors. For his freshman and sophomore years it should make comparatively little difference what he takes in classes as long as he keeps to almost any program outlined at competent institutions. These ordinarily include general botany and general zoology, inorganic chemistry, physics, mathematics, economics, history, foreign language, rhetoric and English composition.

The student should not be over-anxious to get started on courses in his field of special interest. The first two years of college is no time to specialize; they should be spent in laying a sound groundwork for future study. In addition to the basic sciences, courses in English are of distinct value. The fact might as well be recognized that a scientific worker *must* be able to write and speak well if his endeavors are to count for the most. Though he may detest doing it, if he is wise he will not spare himself in perfecting his English, in school and out.

Underclassmen should try to take the various required courses in the order that the faculty advisers suggest. If one attempts to do about as he pleases, he may get himself entangled in all sorts of scholastic grief. If he postpones much required work, aside from being handicapped throughout his undergraduate study by a lack of fundamental subject-matter he should have had, he will find his schedule in an awkward state of unbalance and he may even be compelled to carry extra courses or attend an extra term or two before he can graduate. Only if financial or other exigencies necessitate irregular attendance may a student as a rule profitably depart from the regular academic procedure.

It should by no means be surmised that routine adherence to a prescribed series of courses will fit one for a career. Broadly, one gets out of college about what one puts into it, however stale may be this platitude. The well known collegiate philosophy of "get by" may enable one to pass the minimum requirements for a degree with a minimum of effort, but what of it? Bachelor's degrees are not so rare any more that they alone assure one of any sort of job, to say nothing of special opportunity.

Some remarks on scholastic standing: Grades may be imperfect criteria of what a student actually knows, but they constitute about the only concrete record of his efficiency. That instructors are sometimes unappreciative or even unfair, that students not infrequently obtain better grades than they deserve by cheating or through tactics such as "handshaking," is not to be denied. Ob-

viously, it is not the simplest thing for students working their way largely or in part through college to make the highest of averages; illness, fatigue and unavoidable distractions may also complicate matters. In the main, though, consistently high or consistently low scholarship speaks quite authoritatively and carries no trivial weight when, for example, applications for fellowships are being considered Moreover, low scholarship may mean refusal of admission to graduate schools

All in all, what a student gets out of school is essentially up to him; he can find about what he looks for, the fine and the dross If a certain course falls below his expectations he should have sufficient mental balance to make the best of it, regardless. The mere fact that he may consider a certain professor's lectures empty should not prevent him from digging what substantial material he can out of the text-books.

For junior and senior years, heavier biological courses may be recommended Vertebrate and invertebrate zoology, adequate plant morphology and taxonomy, genetics, courses in field zoology and field botany should be highly desirable. Courses in science other than biological should include organic and physiological chemistry, geology (preferably with some reference to soils), and probably meteorology, and theory of statistics or biometry.

The question might arise as to the advisability of taking courses outside of the scientific field in which one intends to specialize. In answer to this it may be pointed out that no real ecological problem can be confined within the narrow limits of a specific field; it will have ramifications extending in every direction. One may not necessarily be expected to conduct research in all related fields, but it will behoove him to be able to make intelligent inquiry of other specialists when confronted by novel developments or technical obstacles. Nor is an investigator's scientific rating raised if he can not see far enough out of his professed subject to avoid basic blunders of a kind surprising from college-trained men.

English and public speaking should be continued, similarly, foreign languages (German, if French was taken in high school, or *vice versa*). If the student plans to go on for graduate work—which he almost has to do if he hopes to make the most of his possibilities in research—he can well remind himself that a reading knowledge of either French or German is required for a Master's degree; both, for the Ph D These are not empty requirements—he will find use for the languages.

Extra-curricular pursuits need to be accorded the proper emphasis. Summer employment, where one has any choice, should be of such nature as to provide more than financial assistance. Temporary jobs at biological stations, museums, and camp and outdoor work of many kinds may offer invaluable experience. Often is it judicious to take a comparatively low paying job that has unusually advantageous features otherwise In case the student is young and has an opportunity to accompany a scientific expedition, for instance, the interruption of formal schooling for a year or so might not be unthinkable

And it will be no handicap to one's future career if he learns to fit painlessly into social activities, if he can converse intelligently on a diversity of topics ranging from sports to arts. Again, this calls for balance, lest he gravitate into extremes not in keeping with his permanent welfare.

Let us discuss graduate training.

While small or medium-sized institutions may be entirely suitable for undergraduate studies, it is generally more satisfactory to take advanced degrees at big schools having superior personnel

and equipment. Certain departments in certain schools may have international reputations for their strength in particular fields. This article can not make specific recommendations other than to advise the student to select his school on the basis of what he wants and can get. He should understand, too, that graduate work may mean a far faster pace with more exacting demands than anything he had even imagined previously. In many graduate departments, grades below the equivalent of "B" rate as failures.

A prospective graduate student should strive to secure a fellowship or an assistantship in the department in which he intends to carry on his major course work An arrangement of this sort, besides furnishing a small stipend, may allow him fee exemptions and other privileges, give him greater opportunities for contacts with authorities in the field, and permit him actually to live in a biological atmosphere. The assistantship appointee will, nevertheless, find his progress toward a degree slowed down by regulations and by the pressure of his duties; ordinarily he will have to plan on a year and a half to two years to complete a one-year full time graduate schedule.

Among the courses appropriate for the first year of graduate study might be listed parasitology, human physiology, psychology, animal ecology, organic evolution, entomology, ornithology, mammalogy, and vertebrate embryology. This is about the time, also, when most students get their first real taste of research although they may have worked on minor problems earlier in their academic career. Problems having to do with wild vertebrates, and which, if desired, could be amplified into doctorate research, should be sought.

The department or the institution may or may not require a Master's thesis. Similarly, contingent upon the policy of the school and the suggestions of faculty advisers, it may be optional with the student to take his Master's examination and degree, or to omit the Master's and go on directly for the Ph.D. Commonly the Master's is taken.

One contemplating doctorate study should take inventory of himself, weigh candidly the question of his ability to make the grade. He should talk this matter over with his advisers, who ought to know something of his capabilities after a year of graduate class work. He should decide whether he is willing to pay the price

The minimum price is two more years' grind after the Master's or equivalent, often of an intensity inconceivable to those who have not gone through it. Doubtless to persons of natural brilliance or exceptional background the achievement of the doctorate may be in no way an ordeal, but the chances are that practically any one of good mental equipment who finishes in two years will have to travel at top speed, and considerably faster than he ever thought he could.

Granted that the student expects to continue, he should at an early date get exact information as to what courses he has to take for a major in Zoology and a minor in Botany. The course work prescribed for doctorate study is not necessarily to be thought of in terms of credits; it varies with the student's academic status and evident needs and is prescribed to give a well rounded foundation for major and minor fields. There may be assigned heavy outside reading entirely apart from course work.

Although the student will register largely for the courses his faculty committee thinks he ought to, he may wish to take others having a particular bearing on his planned life-work. Histology, bacteriology, more chemistry, physics, or mathematics, courses in techniques—these and others may be worth consider-

ing. It stands without saying that one should investigate the content of a given elective before choosing it too readily on the attractiveness of its title.

Most of the Ph.D. course work is culminated about the time of the preliminary examination. This is the one that counts. It is taken when the faculty decides that the student is ready, no earlier than toward the end of the second graduate year. There is hardly any limit to the amount of useful reviewing that could be done in preparation for the preliminary examination, as long as one safeguards physical and mental health. The preliminary examination passed, the Ph.D. candidate devotes most of his time to research and the writing of his thesis He may take another course or two if he desires or if his advisers decide for him, and he will probably attend seminars in his major and minor subjects. In about a year after his preliminary examination he may hand in his thesis, take his final examination, and, if satisfactory, receive at commencement the degree of Doctor of Philosophy.

After the Ph.D, then what? Perhaps there will be a job. Perhaps the job will be exactly what is wanted; perhaps it will not. Perhaps there will be no job at all. Let no one be deluded into believing that with the acquisition of the degree one acquires relief from such little cares as making a living, getting along with people, and so on; or that the degree will be held as an object of obeisance by the populace at large Indeed, post-commencement experience might be quite the opposite. With respect to this matter, too, there is need for balance.

One could well get straight in mind what a Ph.D. in biological sciences does and does not stand for. It is intended to signify, in short, that its possessor has a general knowledge of biology and an intimate knowledge of some special field, that he is capable of doing independent research. It is intended to signify that he is academically trained. Informally, some may express the meaning of the doctorate in words to the effect that its recipient has proven his capacity to take punishment in a more or less creditable manner. Whether one allows himself to become broadened or narrowed, tempered or warped, depends more upon the individual than upon the academic routine.

The Ph.D. does not assure one of infallibility in judgment nor of inexhaustible funds of information nor of supreme material advantages. It does not assure one of the "inside track" in competitive relations with one's fellow men. It does not assure one of happiness nor of any of the tangible and intangible objectives toward which we strive. It does not assure one of anything; it does not guarantee anything. It is but the certificate of a formal education.

Suppose that one had invested weary years in preparation for a career of wild life research and had sacrificed and fought and gambled for the fulfilment of his ambition, what would be his prospects of finding a position into which he could fit, with opportunities to do interesting and productive work and to make a comfortable livelihood? I don't know. There may be openings on the staffs of universities or agricultural colleges, federal or state biological surveys, national or state parks, fish and game departments, or other public or private organizations as endowed foundations, sportsment's associations, large hunting clubs, estates and conservation societies. There may not be. I know of no profession where one may feel free from uncertainty, but that of wild life research is, at any rate, far from being overcrowded at present, regardless of what it may become in the future.

Why isn't it overcrowded, when in America alone hundreds of careers have been devoted to the natural history of

hundreds of vertebrate species which we designate as "wild life"?

The earlier work dealt almost entirely with the classification of these species and the determination of their evolutionary affinities. Subsequent work dealt with the economics of wild life. Now, the time is ripe to study wild species from the standpoint of their environment, so that they, and thus their inherent values, can be intelligently conserved.

Deliberate control of wild life environment for conservation purposes had hardly begun a decade ago. The ecology of very few species has been worked out with any semblance of thoroughness. Every field, every woodlet, every hedgerow, every marsh presents problems unfathomed by human minds but vital to a harmonious integration of civilization and nature, problems innumerable and scarcely touched. Fluctuations in plant and animal populations, predator and prey relationships, direct and indirect competition of native and exotic species, life histories, environmental factors influencing reproduction and fitness, physiology and behavior—here we have realms of unknowns, plenty to do and an urgent demand that it be done, particularly on game birds and mammals, fur-bearers, and other economically important forms. Some work of this sort is under way in various sections of the country and more is scheduled, but, as could be expected, many worthy programs have been severely cramped, if not shelved, on account of the current financial difficulties.

No one can foresee precisely where events and the dominant social trends will take us. Admitted that we do not know for sure whether the years will find wild life research on the ascendency or on the wane, the training for this special field is not so specialized as to incapacitate one for work in other biological fields, should such be desirable or imperative. Few are the courses suggested which would not be of value to persons engaged in nearly any biological teaching or research. Even were one ultimately to take up a profession remote from academic or economic biology, still the biological training should be anything but a dead loss. As living creatures, we can not divorce ourselves from life and life's principles, whatever we do. As living creatures, ourselves profoundly affected by ecological dynamics, a knowledge of salient ecological phenomena conceivably would not be to our disadvantage, however glaringly our lives deviated from careers originally planned.

SCIENCE IN CHAUCER

By PERCY A. HOUSEMAN
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IN the January, 1932, issue of this journal, Professor D. F. Fraser-Harris has paid eloquent tribute to the remarkable breadth of scientific information and the penetrating powers of observation which Shakespeare possessed. Professor Fraser-Harris has made a valuable contribution toward bridging the gap which all too frequently separates different branches of human activity and interest. We are gradually coming to realize that our work, play, love and worship need not and should not be kept in separate pigeonholes Science should recognize its debt to literature as freely as literature should welcome the companionship of science. With this thought in mind, it seemed of interest to point out the wealth of scientific knowledge displayed by Geoffrey Chaucer, that genius of English literature who lived two hundred years before Shakespeare.

It is a matter of surprise and regret that Chaucer is so generally neglected by the reading public. To be sure, the difficulty with the spelling, pronunciation and vocabulary of Middle English is something of a deterrent, but this obstacle quickly vanishes as familiarity is acquired, and is actually transformed to a feature of attraction. It must further be admitted that some of Chaucer's themes are unseemly, judged by the standards of good taste of today; but it must be remembered that there are many unseemly people in the world, as Shakespeare knew only too well, and unseemliness can not be ignored if literature is to portray life clearly and as a whole. In Chaucer's defense, if indeed defense be needed, it may be pointed out that his occasional Rabelaisian robustness is properly balanced by the truly religious spirit in which he often writes, and by the catholicity of his vision. In his love of everything in the world—the rocks, the trees, the birds, the sunrise and the common man—he stands second to none. As far as science is concerned, it is a question whether in knowledge and penetration he does not actually surpass Shakespeare. Remembering that Chaucer lived in the second half of the fourteenth century, his acumen in science is amazing There is hardly a branch of it in which he does not evince both interest and insight, so that the commentator is confronted with an embarrassment of riches.

Starting with what may be called kitchen-chemistry, we note that Chaucer has a weakness for spices and herbs. Frequent reference is made to clove, cinnamon, anise, caraway, ginger,

> And many a spice delitable
> To eten whan men rise fro table.

He must have been particularly fond of licorice, references to which are scattered through his works. The "pore scoler" of the Miller's Tale is described as being "himself so swete as is the roote of licorys." Another character, Absolon, in the same story "cheweth lycoris to smellen swete,"—a clear recognition by Chaucer of the digestive properties of what we now know as enzymes. Still another member of the distinguished family of Canterbury Tales is Sir Thopas, who describes his passage through a forest in which "ther springen herbes greet and small," and among them the licorice plant. When Sir Thopas returns home, he calls to-

gether his "mynstrales and gestours," who regale him with "wyn, gyngebred, licorys" and other delicacies. Another favorite drug of Chaucer is valerian, which in Middle English is called "cetewale," and which appears to have been used both as a sedative and as an ingredient of perfumes

In the field of metallurgical-chemistry Chaucer has a remarkable fund of information. His writings are rich in the fantastic lore of alchemy, but Chaucer is fully aware of the roguery which was so frequently practised by unscrupulous alchemists to dupe the unwary with claims for the transmutation of base metals into gold and silver. Vain efforts "of a single pound to make tweye" form the plot of the fascinating "Canon's Yeoman's Tale." The Yeoman, whose office was to "blowe the fyr," bemoans the repeated failures:

Yet is it fals; and ay we have good hope
It for to do, and after it we grope.
But that science is so far us before,
We never can, although we had it swore. . . .
That slippery science hath me made so bare,
That I have no good, wher that ever I fare

Then follows a long list of substances and of apparatus used in the preparation of the "yngottes"; orpiment, litharge, sal armoniak, verdegres, boras, arsenek, brimstoon, unslekked lym, glayre of an ey (white of an egg), alym, resalgar, and many others, treated in alembikes, concurbites (distilling flasks), viols, sublimatories, croslets (crucibles) and descensories (percolators?); a list which would have formed a goodly contribution to a chemical dictionary of that day. The woeful outcome of the experiment will strike a sympathetic note in the heart of many a modern chemist:

And wit ye how? ful ofte it happeth so,
The pot to-breketh, and farwel, al is go.

Later comes the climax of the tale, with the rascally Canon slipping an ounce of silver into the assay in order that it may be found at the end.

Just as Chaucer's chemistry contains much alchemy, so his astronomy is naturally admixed with a good deal of astrology. He planned an elaborate work called "A Treatise on the Astrolabe," but like many of his undertakings, it was never finished, less than two of the contemplated five parts being completed. The "Treatise," in so far as it was written, consists of a elaborate description of a very intricate instrument and of its astronomical uses. On the Astrolabe were marked the signs of the zodiac together with all kinds of points, lines and angles. It was used to compute the altitude of heavenly bodies, longitude and latitude, the points of the compass, etc., by means of shadows, angles, and what Chaucer quaintly calls "pin-prikkes." That Chaucer's ten-year-old son, for whose edification the work was intended, could ever have comprehended a single word of it, is past belief.

Chaucer makes frequent reference to the determination of the date and the time of day from the position of the sun. So for example in the words of "Oure Hoste" to the Canterbury pilgrims:

Oure Hoste saw that in heven the brighte sonne
The ark of his artificial day had ronne
The fourthe part and half an hour or more;
And though he were not depe expert in lore,
He wist it was the eightetenthe day
Of April that is messanger to May;
And saw wel that the shade of every tree
Was in the lengthe the same quantitee
That was the body erecte, that caused it;
And therfore by the shadwe he took his wit,
That Phebus, which that shoon so fair and brighte
Degrees was five and fourty clombe on highte;
And for that day, as in that latitude,
It was ten of the clokke, he gan conclude;

Of medicine Chaucer writes relatively little, though one of his pilgrims is a "Doctour of Physik" who was "a very parfit practisour" and whose partnership with the pharmacist is described in satirical vein:

Ful redy hadde he his apothecaries,
To send him drugges and electuaries,
For eche of them made the other for to wynne;
Their frendshipe was not newe to beginne.

Chaucer is well aware of the limitations of drugs when he says of Arcyte in the Knightes Tale:

And certeynly where nature will not wirche
Farwel physik; go bere the man to chirche.

Then follows a vivid picture of the symptoms of death:

Swelleth the brest of Arcyte, and the sore
Encreaseth at his herte more and more . . .
For from his herte up to his brest was come
The cold of deth, that him had overcome.
And yet moreover in his armes two
The vital strength is lost, and all i-go
At last the intellect, withouten more
That dwelled in his herte sik and sore
Gan fayle, when the herte felte death,
Dusked his eyen two and fayled his breth. . . .
His spiryt chaunged was and wente there
As I cam never, I cannot tellen where.

Elaborate preparations are made for the cremation of Arcyte's body. Here is a list of twenty trees which are made to contribute to the funeral pyre:

Ook, fir, birch, asp, aldir, holm, popler, wylugh, elm, plane, assh, box, chestnut, laurer, mapul, thorn, beech, hasel, ew, whippeltree (cornel).

No less keen than his interest in trees is Chaucer's delight in birds and flowers. Thirty-four different kinds of birds are enumerated in the assembly for his "Parlement of Foules," and many times throughout his poems he rhapsodises on the "briddes" and "floures":

Herken these blisful briddes how they sing
And see the freshe floures how they spring
Ful is mine heart of revel and solas.

It is when thus inspired by natural science that he exclaims:

Farwel my book and my devocioun.

The glory of the sunrise and sunset moves him deeply, yet in his poetic admiration he does not forget to record the physics of the ruddy dawn:

The vapour which that up the erthe shedde
Maketh the sonne seme brood and red.

It would be difficult to produce a more concise statement of the screening effect caused by the long layer of air through which the sun's rays must pass at sunrise and sunset.

From the point of view of scientific interest, perhaps the most brilliant and ingenious work of Chaucer is his "Hous of Fame." Here he boldly invades the realm of physics and invents a Theory of Sound. The plot of "The Hous of Fame" centers upon an aerial cruise which Chaucer takes while clutched in the talons of a golden eagle. When far above the earth, the eagle, being in a position to state its views without fear of contradiction, proceeds to lecture Chaucer on sundry scientific and philosophical subjects. At the end of a one-sided dissertation on the cause of sound, the eagle asks Chaucer if he does not agree that its theory of sound stands proven. Chaucer, diplomatic as well as sagacious, thinks of the talons from which he hangs so dizzily suspended and with delicious humor limits his reply to the single word "Yis." The eagle's theory of sound is derived from the general idea advanced by Aristotle that everything has a natural environment or home at which it seeks to arrive. The natural home of the river is the sea, of heavy things "downward," and of light things "on highte."

Sound is nought but air y-broken,
And every speche that is spoken,
Lowde or pryvee, foul or fair,
In his substance is but air;
For as flame is but lighted smoke
Right so sound is air y-broke. . . .

The air is twyst with violence,
And rent: lo, this is my sentence

Sound is conceived as breaking through the lower air and rising in ever-widening concentric circles to the upper levels, much as a stone cast into water causes circular waves to spread out. All sound

thus arrives at last at the "Hous of Fame," where it resounds like the

> Betying of the see against the roches holowe
> Whan tempest doth the shippes swalowe.

The height of scientific fantasy is reached by every speech assuming the likeness of the speaker, so giving the listener the ability to pass backward through time, and hear the words as they issue from the speaker's lips

In his article on biology in Shakespeare, Professor Fraser-Harris devotes a good deal of attention to Shakespeare's views on sleep. It may be fitting to conclude this essay with a consideration of Chaucer's reference to sleep, and more particularly to dreams and visions Shakespeare's reference in Macbeth (ii, 2) to sleep as a nourisher is anticipated by Chaucer in "The Squire's Tale" where he speaks of

> The norice of digestion, the sleep.

Of the ravages caused by insomnia he says in "The Death of Blanche the Duchesse".

> I have gret wonder by this lighte
> How that I live, for day nor nighte
> I may slepe wel nigh nought, . . .
> For Nature woulde not suffise
> To none earthly creature
> Not long time to endure
> Withoute slepe.

Dreams and visions (swevenes) play an important rôle in Chaucer's work, and the use of this device was quite fashionable in the Middle Ages An outstanding example is the French poem "Roman de la Rose," of unknown authorship, which was translated by Chaucer. Chaucer followed this type in his dream poem "The Death of Blanche the Duchesse," and dreams are also prominent in "Troilus and Criseyde," "The Hous of Fame," "The Parlement of Foules," and in the "Nun's Priest's Tale" of Chanticler in the Canterbury Tales. He seems not quite able to make up his mind whether dreams are no more than the result of dining not wisely but too well, or whether they have real meaning. The opposing views are admirably set forth in the delightful tale of Chanticler and Pertelote The adoring wife Pertelote calls upon Cato to support her view:

> Alas! and can ye be of dremes agast?
> Nothing, God wot, but vanitee at last.
> Dremes are engendred of repletions
> And often of fumes and ill complexiouns
> Whan humours be too abundant in a wight.
> Certes this dreem, which ye have had tonight
> Cometh of the grete superfluitee
> Of your blood and red colour, pardee

But Chanticler maintains stoutly, and with many references to authorities, that men

> Have wel founden by experience
> That dremes be significaciouns
> As wel of joye, as tribulaciouns . .
> And some tyme dremes ben (I say not alle)
> Warnyng of thinges that shall after falle . . .
> Shortly I say as for conclusioun
> That I shall have of this by visioun
> Adversitee

That Chanticler does in fact shortly meet with such adversity as almost costs him his life would certainly lend some support to his views! Chaucer is evidently much puzzled by the whole subject and devotes the sixty-five lines of the proem of the first book of "The Hous of Fame" to wondering what is the cause and significance of dreams:

> And why the effect followeth of some,
> And of some it shall never come;
> Why that is an a-vision,
> And this a revelacioun,
> Why this a fantom, why these oracles.
> I know it not

For those who know Chaucer well and therefore love him, it is hoped that this paper, sketchy though it be, will be of interest in calling attention to the extraordinary depth of his insight into many branches of science. For those who love him less because they know him less, it may serve as an introduction which may ripen into a friendship well worth while.

SCIENCE SERVICE RADIO TALKS

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INSULIN AND DIABETES

By Dr. VINCENT DU VIGNEAUD

PROFESSOR OF BIOCHEMISTRY, SCHOOL OF MEDICINE, THE GEORGE WASHINGTON UNIVERSITY

IN spite of the fact that diabetes has been known for centuries it was not until twelve years ago that a means of combating this hitherto fatal disease was furnished by the discovery of insulin. As far back as the Egyptian writings of the fifteenth century before Christ, we can find references to a disease which was clearly the diabetes mellitus that we know of to-day It seems rather incredible, though, that it was not until over three thousand years later in the seventeenth century that the excretion of sugar was first suspected Willis, a great English physician, was the first to note this. In describing the disease Willis referred to the fact that the diabetic excretion was sweetish like honey. It is from this observation that diabetes mellitus gets its name, for the term mellitus is derived from a Greek word meaning honey The term diabetes itself simply refers to the abnormally large amount of water excreted. There are in fact a number of kinds of diabetes and one must use the descriptive term diabetes mellitus to refer to the type of diabetes in which sugar is excreted and in which there is also an increased amount of sugar in the blood

Progress throughout the centuries was indeed very slow in the understanding of this fatal disease, when suddenly there occurred an epoch-making discovery in 1889 in Germany by two workers, Minkowski and von Mering. They found that removal of the pancreas, which is a small glandular structure located just below the stomach, produced a fatal diabetes in dogs, similar in all respects to the diabetes mellitus of man. Further work by these investigators disclosed that these animals from which the pancreas had been removed were unable to oxidize sugar in their bodies, sugar therefore accumulated in the blood and was finally excreted by the kidneys

Exactly the same situation occurs in human diabetes mellitus The patient loses the power to burn or utilize sugar in the body and the sugar is likewise lost through the kidneys From the fact that removal of the pancreas should cause such a condition these early investigators concluded that some substance was produced by the pancreas which enabled the body to utilize sugar and that for some reason the pancreas of a diabetic failed to produce this substance.

Von Mering and Minkowski therefore attempted to prepare extracts of this hypothetical substance from the pancreas to find out whether the administration of the extract to animals that had their pancreases removed would enable them to utilize sugar Their many attempts ended in failure. Others were attracted by these experiments and throughout the ensuing years many investigators tried to prepare active extracts. Either their attempts were greeted with failure or else the results were inconclusive.

Yet there persisted the staunch belief that there must be present in the pancreatic gland a hormone or active prin-

ciple which regulated sugar oxidation and if extractable would offer means of combating diabetes. It was not, however, until twelve years ago that definite substantiation of this belief was established. This great advance was accomplished by two young Canadians at the University of Toronto, Banting and Best. They were successful in preparing an extract of the pancreas which would lower the blood sugar, bring about oxidation of sugar in the body and what is paramount to all, save the lives of many diabetics.

Although the many investigations of the preparation of active extracts of the pancreas in the years intervening between the work of von Mering and Minkowski and Banting and Best were not successful in establishing unequivocal proof of the existence of insulin, yet very much worthwhile information was gained. Some workers such as Zuelzer, Scott, Murlin and others had without question obtained active extracts and their work contributed much to the fund of knowledge and experience which finally culminated in the dramatic triumph of Banting and Best. It does not detract from the triumph of these latter workers to emphasize the significance of the contributions of those who laid the foundations upon which this brilliant work was built. As many of the earlier workers obtained negative results on making simple extracts of the whole pancreatic glands it began to be suspected that the digestive enzymes of the pancreas, which would be present in the extracts, destroyed the insulin. The pancreas, you see, is also a digestive organ and produces digestive enzymes or catalysts that are poured into the intestinal tract to aid in the breakdown of foodstuffs.

Under the microscope two types of cells can be identified in the pancreas. One type of cell produces an enzyme secretion which is collected by little tubes or tubules which unite to form larger tubules until finally the secretion is emptied into the intestine through one or two large ducts. In the intestine this so-called external secretion aids in the digestion of foodstuffs. The other type of cell occurs in little groups which are called the islets of Langerhans, named after the man who discovered them. Evidence had already accumulated that it was these cells that must be the ones that produced a sugar regulating hormone, if such a compound existed.

If, then, a simple extract with water was made of the whole pancreas, then the digestive enzymes present in these other cells might destroy the active sugar regulating hormone that was present in the islets of Langerhans. But some other workers had already shown that if in an animal the ducts that carry the external secretion into the intestine be tied off, degeneration of the cells that produce the enzymes would take place, but that the islets of Langerhans would remain intact. Such a pancreas would therefore have no digestive enzymes in it but might contain the sugar-regulating hormone. The latter might then be extracted without fear of destruction by the digestive enzymes. This was the basic idea behind Banting's experiment. Banting and Best actually carried out such an experiment and made extracts of pancreases produced in such a way as I have just indicated. They were able to keep a diabetic dog alive by the administration of these extracts. It was this brilliant achievement which finally led to the potent extracts which are used medicinally.

After this successful experiment they then took advantage of an observation that had previously been made, that the islets develop long before the other type of cells in the animal before birth. They therefore extracted the pancreases of unborn animals obtained from the slaughter houses. These extracts were also efficacious. With the experience they now had at their command they

turned to making extracts from normal beef and pork pancreases. They prevented the enzymes of the external secretion from destroying the insulin by extracting the insulin with acid alcohol; this is the basis of the methods now used in preparing insulin solutions for medicinal uses.

But what is it that is present in these extracts that produce such profound physiological effects? These extracts of course contained a host of other compounds besides insulin. Chemists all over the world started on the quest of isolating the active principle itself from these extracts. They wished to isolate it in chemically pure form so that its chemistry could be studied. It proved to be very elusive and it was not until five years later that Prof. John J. Abel of the Johns Hopkins University succeeded in isolating the pure crystalline insulin. The obtaining of insulin in the pure state opened the possibility of really attacking the chemical nature of insulin.

The evidence to date indicates that insulin is a protein-like compound. It is extremely complex, and all the constituents that go to make up the molecule are not yet known. Work is in progress in our own and other laboratories to identify these other constituents. One of the striking facts concerning the chemistry of insulin is the high percentage of sulfur that is present. There is much evidence that the sulfur is intimately connected with the activity of the compound. Further work is being done on this relationship. Another line of attack that is being used at present is an attempt to find out if there is within this larger molecule a nucleus which is responsible for the physiological action. This is an attractive hypothesis but it must be admitted that there is no evidence for this idea as yet. Another approach to the insulin problem is the synthesis of various compounds in the hope of finding one that will replace insulin and which might give some idea as to the groupings responsible for the lowering of blood sugar by insulin. But so far, there has been synthesized no compound that can take the place of insulin.

Probably one of the most important aspects of the insulin studies is the attempt to modify insulin in such a way as to retain its physiological activity but so change it that the enzymes in the intestinal tract will not destroy it. In this way it may be possible to develop a method of giving insulin by mouth and avoid the injection of the insulin under the skin which of course becomes very bothersome to the diabetic. It would be a great boon to the treatment of diabetes if this could be accomplished. Yet I must point out that at present there is no preparation of insulin that can be given by mouth which can be relied on to take the place of the regular insulin which must now be given by injection.

It can readily be appreciated how much remains for future research to accomplish. Not only is there much to be done on the chemistry of the compound but at the present time it is not known just how it works in the body. Understanding this, it is to be hoped that a better understanding of diabetes will be arrived at, and to actually find out what is the cause of this malady which is not known at the present time. If the cause is known then possibly a means of preventing it can be worked out.

In this connection it might be mentioned that some very recent work is beginning to throw new light on the diabetic question. It has been found recently that if the pituitary gland, which is a small gland located at the base of the brain, is first removed from an animal and then the pancreas removed, strangely enough, no diabetes occurs. Furthermore extracts of the anterior part of the pituitary gland can cause a diabetic-like condition in the normal animal. This shows that there

is a very intimate relationship between the pituitary and the pancreas, and it is very suggestive that at least in some cases of diabetes an overactivity of the pituitary gland rather than lack of insulin may be responsible for the condition. We can confidently look forward to new work within the coming years from many laboratories throughout the world that will add much to our knowledge concerning this important question It is entirely possible that our views concerning diabetes and utilization of sugar may be radically changed by this new work.

The entire story of insulin and diabetes emphasizes even more strongly the underlying basis that chemistry affords in the study of modern medicine and further the value of the experimental approach to these complicated clinical questions.

MATHEMATICS IN A CHANGING WORLD

By Dr. ARNOLD DRESDEN

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FOR the majority of my invisible audience, the word mathematics will conjure up memories of youthful experiences, tearful for some, perhaps aglow with the sense of achievement for others; memories of multiplication tables, of percentage calculations and of similar amusements All these things are as fixed as the laws of the Medes and Persians, unchangeable as the succession of the seasons, rigid and void of imagination. Whence, then, does this subject derive its importance for the modern rapidly changing world in which every day brings its new problems and its new fashions? To appreciate the importance of mathematics for the maintenance of human existence in such a world we must go beyond the superficial aspects of its elements as taught in the schools and attempt to gain some insight into its fundamental characteristics.

Let us begin by taking a somewhat closer look at the nature of the forces acting on our environment It is granted by every one that they are complicated in character, that they do not always bring us forward, that frequently we stand still, that many times we retrograde. The situation bears a certain resemblance to that of the motion of the celestial bodies in the days before Copernicus, Kepler and Newton The motion of the planets was studied from the terrestrial point of view and elaborate systems of epicycles were necessary to introduce some order into their lawless behavior. But when the problem was considered from the point of view of the sun as a central body, a great simplification was effected. The seemingly erratic character of the planetary motion was explained on the basis of a simple hypothesis, that of universal gravitation. To-day we understand that the irregular way in which the planets appear to move arises from the simultaneous operation of a number of motions, each simple and each capable of quite elementary explanation. This suggests a possible direction in which progress may be made in the understanding of our human problems. They have been studied preponderantly from national and even sectional points of view. Now it is one of the fundamental tenets of mathematics that the relations which it studies are never completely understood until they have been considered from the point of view of each of the elements which enter into them. This is pregnantly expressed in a saying of the famous German mathematician Jacobi: "Man muss immer umkehren" (we must always turn things

about). This principle would lead to a thoroughgoing reexamination of the baffling problems which confront us. Is it not possible that they will prove more amenable to explanation if looked at from a world point of view? May it not then turn out that the apparently capricious way in which our world behaves will prove to be due to the simultaneous operation of a number of independent forces, each pulling or pushing in its own way, but each capable of exact understanding? If this should be the case, an analysis of the complex results into their simpler constituents would evidently be of capital importance. Mathematics possesses many methods for such analysis, the interested listener will find examples in the literature of our subject.

Moreover, it is not unlikely that some of the simpler elements whose combination produces our complexities are periodic in character That is to say, that they pass through a cycle, repeating over and over again a definite sequence of stages It is well known that several attempts have been made to discover such periodicities in our economic life. The wise words attributed to King Solomon that "there is nothing new under the sun" may be interpreted to mean that periodic laws control all our experience. Mathematics embraces elaborate theories concerning periodic phenomena.

We must look at another aspect of our question. As a science advances, be it a natural or a social science, we secure not only more and more complete data concerning the things that science studies, but we discover that relations exist between various phenomena which at first had been thought of as unconnected. A striking example is Benjamin Franklin's discovery of the identity of lightning with an electric discharge. Modern times have brought recognition of the fact that the productivity per hour of a factory worker is in some way dependent on the length of the working day and on the physical conditions under which his work is performed We have also learned that the yield of wheat per acre depends upon the nitrogen content of the soil, that the power of resistance to disease of the human body is related to the age of the body as well as to the corpuscular content of its blood, that the index prices of commodities depend upon the amount of free gold, and so forth through a long list of subjects and a wide range of fields. But our knowledge of these dependencies is far from complete. We may know that two things are related, but not what the relation is, nor what conclusions are to be drawn from their relatedness, what predictions it justifies. When two changing magnitudes are so related to each other that to a given amount of one of them, there corresponds a definite amount of the other, we say, in technical language, that they are functionally related, that one is a function of the other Thus we would say that the productivity per hour is a function of the length of the working day, that the length of a metal bar is a function of its temperature, that the wheat yield per acre is a function of the nitrogen content of the soil, and so on.

A large part of mathematics consists of the study of functional relations, of determining that one which comes nearest to expressing the connection between two accurately measured varying magnitudes, of deducing the properties of such functional relations, of deriving the consequences of their existences. We learn, for instance, that the increase of a certain cause may sometimes carry with it an increase of effect, but at other times a diminution. If we toss a ball into the air the height to which it rises increases with the speed with which the ball is propelled upwards. But if one teaspoonful per day of medicine cures an illness in 10 days, it does not follow that ten times that amount will bring relief in one day, unless it be relief by extinction. Does it need further argument to convince us of the importance for the

understanding of our environment of the study of functional relations?

In his dealings with such relations between variables, the mathematician is not concerned with any concrete interpretation of these variables, but merely with the form of the relation connecting them. The physicist may have found that the pressure and volume of a gas under constant temperature are so related that the product of the numbers measuring these magnitudes is constant The economist may have learned that the number of producing units and the amount produced by each unit are variables so related that the product of the numbers measuring them is constant. For the mathematician these two observations are but two instances of a functional relation between two variables whose product is constant. He will study this functional relation so as to obtain all its possible consequences and then turn his results back to the physicist and the economist so that they may interpret them each in his own field. Mathematics is therefore an abstract science, interested not in particular, concrete, instances, but in those elements and qualities which are common to a large variety of concrete cases. A mathematical formula holds within its abstract form an endless mass of isolated conclusions. This character of the subject is evident even in its elements. When a child learns that 4 plus 5 equals 9, it has within its grasp numberless special cases, *e.g.*, that 4 apples added to 5 apples makes 9 apples, that 4 books added to 5 books makes 9 books, and so forth. It is its abstract character which gives mathematics its great power of adaptation to the problems and requirements of an ever-expanding world.

Finally I must call brief attention to the division of mathematics which is known as the theory of transformations. When you move objects about on a table, when you toss a ball up into the air, when you send out sound waves from your vocal chords, when an acorn grows into an oak tree, when the image of an object is formed on the retina, transformations take place. Mathematicians have realized the importance of the nature of a transformation and have classified them according to their characteristic properties, rather than with respect to the objects on which they operate; they have inquired, for each type of transformation, whether anything remained unchanged when such transformations are carried out—in technical language, they have looked for invariants. It should be expected that the determination of the invariants of a system reveals its fundamental properties. When objects are moved about in space, their shape and weight are presumably invariant. The only properties of an object which sight can reveal are those which are invariant under the transformation from object to retinal image. Many of the problems which a changing world puts before us can be summed up in terms of the theory of transformation. To find out the properties of the transformation, to discover what remains invariant under them, these are fundamental problems of which even a partial solution only would be of great value.

These four aspects of the science of mathematics, its powers of analysis, its concern with functional relations, its abstract nature and its interest in invariants under transformations are the ones to which I want to direct your attention in this brief presentation of the significance of mathematics in a changing world. They are all abstract in character; mathematicians cultivate them for their inherent interest. They have been turned to fruitful account probably because they reveal fundamental qualities of the human mind; but these applications belong to the sciences, natural and social.

WHAT X-RAYS CAN TELL US ABOUT ATOMS

By Dr. SAMUEL K. ALLISON

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X-RAYS were discovered in 1895 by the German physicist, Wilhelm Röntgen, then working at the University of Würzburg. The importance of the discovery to the medical profession was at once recognized. In a few weeks after Röntgen's announcement the new rays had been used in the diagnosis of bone fractures and in the location of foreign bodies in wounds. To-day it is difficult to imagine surgery and dentistry being practised without the use of the information readily obtained from x-rays.

It is not of these applications to the medical profession, which are familiar to every one, that I wish to speak in this brief talk. I shall, however, try to give some idea of the use of x-rays as a tool in the investigation of the fundamental problems confronting the physicist and the chemist in their studies of the ultimate nature of matter. It is probably not popularly realized that the advances in the sister sciences, physics and chemistry, achieved by the use of x-rays have been fully as great as the resultant improvements in medical and surgical practise.

I shall try to give a brief explanation of the extraordinary importance of x-rays as a scientific tool. In our studies of the structure of matter, we are interested in atoms, and in the electrons which make up atoms. Atoms are extremely minute things, and we know definitely that they are so small as to be forever beyond the possibility of direct vision, even when aided by the most powerful microscope. This statement is not a criticism of the skill of the instrument makers who construct microscopes; the fundamental reason for the invisibility of atoms lies much deeper than a question of instrument design. It lies in the fact that we see by means of light waves, and the light waves to which our eyes respond with the sensation of sight have wave-lengths a thousand times greater than the diameters of the atoms which we wish to see.

I shall attempt to illustrate the difficulty by means of an analogy. Let us imagine a town on the seacoast with a not too well-protected harbor into which ocean swells are advancing on a calm day. As the waves strike piers, wharves or ships at anchor, reflected waves will be set up which interfere with the advancing waves and with each other, so that the surface of the water near these large bodies is crisscrossed by smaller waves and has especially high humps of water where two wave-crests overlap, and especially deep troughs where one wave-trough coincides with another. The pattern produced on the water in such a case is called a diffraction pattern. Now it is conceivable that a physicist, seeking to enter the harbor in a fog which cut off vision of the shore, could locate the position of large objects by observing the diffraction pattern and thus studying the waves reflected from them. I must here remark, however, that in any actual case the services of a certified pilot would be infinitely preferable, because while the physicist was making the elaborate calculations necessary, the ship he was steering would be likely to crash into the object he wished to avoid.

The point of the illustration is that, although the problem of locating large-sized objects in the harbor by means of the reflected waves is not insoluble, it would be quite impossible to locate the barnacles on a ship or the grains of sand on a beach by such a study. The wave-length, or crest-to-crest distance of the advancing waves, is far too large to reveal such minute details. In an analo-

gous way an attempt to study the positions of atoms in solids, or the shapes of atoms, by means of visible light is bound to fail, due to the great disparity in the wave-length of the light and the dimensions of the atoms. Here is where the x-rays come to our aid. They are similar in nature to light waves, but their wave-length is a thousand times shorter. In studying the diffraction patterns produced when x-ray waves impinge on matter, the physicist has ample time to make his calculations, since, in contrast to the situation in the preceding fanciful illustration, his life is not in danger, and he can actually locate the positions of the atoms, each of which reflects, or in a more technical language, scatters secondary x-ray waves.

As a result of this success, the advent of x-rays eventually caused an upheaval in the venerable science of crystallography. It is unfortunate that the non-technical person has little or no contact with crystals in the sense that the scientist understands the word. In popular speech the word crystal suggests something transparent, especially a transparent jewel, but in its technical sense transparency is not at all an essential attribute of a crystal. To the scientist a large crystal is a solid which has been formed in such a way that it can exhibit its natural shape, which for all substances is one bounded by flat surfaces and edges. The materials with which we come in contact in everyday life, with the exception of glass, can usually be shown under the microscope to be agglomerations of enormous numbers of minute crystals, wedged together. Snowflakes, if examined closely, exhibit the most beautiful regular patterns and are bounded by planes and edges, constituting examples of crystals.

Crystallography is the study of these objects and, due to their great regularity of shape, scientists have long suspected that the atoms of which they are made are not arranged in haphazard fashion, but on the contrary are placed in some very regular array. By the study of the diffraction patterns produced when x-rays strike crystals, the expectations of the crystallographers have been confirmed, and what was previously a guess has been reduced to tabulated numerical values of interatomic distances and designs Thus the positions of atoms in crystals of ordinary table salt is known with great precision. Chemists have long known that table salt contains only two kinds of atoms, those of the elements sodium and chlorine. From the use of x-rays we know that these are arranged in rows and columns throughout space in such a way that in the three principal directions sodium and chlorine atoms alternate

This is a very simple type of crystal, and others, much more complicated, have been unraveled. As the work goes on, scientists are learning more and more about the problem of chemical combination; the relative positions of atoms in solids giving important clues as to the nature of the chemical forces which hold them together.

X-rays can be produced whose wave-length is short enough for the study of the positions of electrons inside atoms. Each electron scatters a wave which interferes with waves scattered by other electrons in the same atom, producing a diffraction pattern the study of which will reveal the electronic structure of the atom.

I shall now mention quite a different way in which we can get information about atoms from x-rays. In the present case, the study of the beam coming from an x-ray tube tells us something about the atoms in the target of the tube. In the production of x-rays, high speed electrons strike against a metal block in the tube called the target. Professor A. H. Compton has given us the following instructive analogy. He compares the process to the impact of machine gun

bullets on a steel wall. The impacting bullets are the electrons, and the noise produced by the impacts corresponds to the x-rays. It is true that most of the x-rays produced in a tube have this noise-like or irregular character, but a careful analysis of the radiation discloses that amid the irregularity there stand out a few simple waves. It is as if the bullets in a few cases penetrated the steel wall and struck a musical gong or bell, causing it to emit a pure tone, which is almost but not quite drowned out by the general din These the physicist describes as characteristic wave-lengths, superimposed on the general background.

It is found that these characteristic wave-lengths depend on the kind of atom of which the target is built; copper, iron, aluminum, and so forth, having different and typical wave-lengths These arise from vibrations of the electrons deeply embedded in the atomic structure, and from the wave-length we deduce the forces with which these electrons are bound

When these characteristic wave-lengths have been determined for a large number of different elements, we find that the elements, arranged in the order of their wave-lengths, fall into the same order as they do when they are listed according to their atomic weights. This regularity convinces us that the electronic structure of atoms is not built in a random manner, but proceeds according to a definite and inflexible plan, at least as far as the inner regions are concerned.

These inner regions in atoms like those of gold and lead we find to be exactly alike, the only difference being that, in the case of lead, the inner electrons are somewhat more tightly bound than are those of gold. How then shall we account for the obvious differences in properties between the two substances; the yellowness of gold and the grayness of lead, the melting of lead at a much lower temperature than gold, and so on?

These properties we ascribe to the arrangement of the very outermost electrons in the atom, which do not give us information as to their positions through the medium of x-rays. It is these superficial electrons which control the properties of matter, with the exception of weight, with which we come into contact in everyday life. It is these which cause oxygen to support life, nitrogen to allow it to stifle, and chlorine to deliberately destroy it.

Thus the study of the characteristic x-rays has enabled us to define regions of the atom to which various properties are assigned. In their interior, from which the characteristic x-rays come, we detect a stabilized region which persists unchanged as the atom undergoes various chemical combinations. I hope that in these few moments at my disposal I have succeeded in giving you a glimpse, at least, of what x-rays can tell the scientist about atoms.

ANCIENT FISH ADMIRERS

By Dr. S. W. FROST
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THE lure of fish has a foundation almost as ancient as man himself. From the dawn of human history, the fish captivated man's eye and satisfied his palate Primitive homes were built along the sea or near watercourses where fish abounded and could be easily obtained So closely was man's early existence associated with this ichthyian that he learned to regard it with reverence and fear We refer to the ancient worship of the Egyptians The Nile not only furnished a staple food supply but replenished the land Thus natural provider, and all connected with it, became an essential part of their belief. The fish was associated with the great genetrix Isis, the wife of Osiris and the mother of Hortus. According to an old legend, the tears of the goddess Isis fell into the Nile, caused the inundation of the river and thus brought the land wealth, which means nourishment. Although Isis has long been forgotten, her fertilizing tears survive Even to-day every one in Egypt knows that the "divine drop" falls from heaven in June to bring about the rise of the Nile. It is no wonder that the fish was vitally impressed on the art of the Egyptians.

The earliest examples of the fish in art are found on stone seals from Ur. More than four thousand years before Christ, numerous intaglios were found, many of them inscribed with fish or fishermen. The fish has been found on the early button-like seals which antedate the beads and cylindrical seals of Babylonia. Another early example is a slate palette, in the form of a fish, discovered in the ruins of Nagada prior to 3000 B.C.

The fish occurs on numerous seascapes as incidental decorations, usually in the rippled waters Bas-reliefs and paintings show that the ancient Egyptian used all known methods of catching fish —spearing with a harpoon, fishing with a line, setting nets and traps A relief on the tomb of Gemneka, the VI dynasty, shows fishermen bringing in their day's catch. They carry their fish on sticks over their shoulders, in slings on their arms and in their hands. A Medum painting depicts two fishermen with a large fish suspended from a staff supported on their shoulders A painting from Nakht and another from the tomb of Khnumhotpû at Beni-Hasan show fishermen using harpoons. A bas-relief in the mortuary chapel of the "Royal Companion" Tiy at Sakkâra illustrates four men pulling in a heavy net A relief from the tomb of Ti shows a number of men fishing with a trap. Two of the men are lifting the trap, while others appear ready to take the fish. On a relief at Koyunjik is seen a Kufu laden with stone and manned by a crew of four. Behind the Kufu a fisherman sits astride an inflated skin with a fish basket attached to his neck.

The Egyptians, Babylonians, Phoenicians and Assyrians had their fish gods and goddesses The Assyrian Ea, of the Nineveh tablets, is an example of a deity half man and half fish. Although this sort of merman deity had its origin in Asia, it found its way to Ireland and was eventually canonized as St. Darerea. The fish god Anou or Dagon, a native Semitic deity, was adopted by the Philistines after their settlement in Canaan. This god is figured on an Assyrian bas-relief from Nimrûd and is also figured on a Chalcedonian coin, which is inscribed with a star above, a winged

MOTIF FROM PHOENICIAN POTTERY
(AFTER PERROT AND CHIPIEZ).

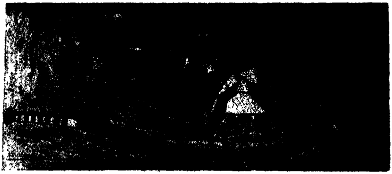
EGYPTIAN SLATE PALETTE
FROM NAGADA, 4000 B. C. (AFTER CHILDE).

figure to the left and the fish god to the right. The Babylonian fish god, Oannes, symbolized fertility. It is thought to be identified with the Assyrian Ea. A copy of this god occurs on a bronze bell now in the British Museum Perrot and Chipiez figure a bronze plaque of questionable origin, but probably from Asia Minor On this plaque two fish gods, "Oannes," are working over the dead. The chief figure is the goddess Allāt, passing through the nether region in her bark. Nergal, the god of Hades, peers over the top of the plaque. The Persian fish god "Iannes" or "Euahanes" is also identified with Ea and is supposed to dwell in the Persian Gulf (Erythraean Sea) rising out of the water in the daytime and furnishing mankind with instructions in writing. Two fish-like Deities of the Chaldeans may be seen on an intaglio in the British Museum.

Western Asia contributes many early examples of the fish motif. It is found on prehistoric painted pottery from Nal, Baluchistan, and is represented in the script of the Indus Valley prior to 3500 B.C. In India the fish is one of the avatars of Vishnu which saved the progenitor of the human race, Manu, from the flood. A typical Assyrian scene, taken from the palace of Khorsabad, shows workmen transporting wood across a stream in boats with numerous fish, crabs and animals swimming about in the water An early Chaldean terracotta tablet shows a native carrying a fish. The fish is also found on one of the boundary stones of Nebuchadnezzar on the upper Nippur River.

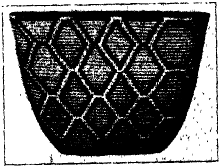
The culture of ancient Crete reveals many representations of the fish. The flying fish fresco from Phylakopi, Melos, is one of the best-known examples. Cretan seals and pottery as early as 900 B.C. exhibit numerous examples of fish patterns. Mycenaean and Cretan fish script resemble superficially Egyptian hieroglyphs. The octopus motif is also found on Cretan pottery of the Minoan period especially from Palaikastro.

The art of Cyprus, like all other countries bordering the Mediterranean, abounds with examples of the fish motif.



FISHING WITH HARPOON, FROM TOMB KHNUMHOTPU
(AFTER MASPERO)

ANCIENT FISH FIGURES
(*Top*) CAT EATING FISH, FROM TOMB OF NAHKT, EGYPT (AFTER WEIGALL). (*Lower left*) PAIR OF FISH FROM UR, DATING ABOUT 2300 B. C. UNIVERSITY MUSEUM, PHILADELPHIA. (*Lower right*) TERRA-COTTA TABLET SHOWING CHALDEAN CARRYING A FISH (AFTER MASPERO).



FISH-NET PATTERN ON COILED BASKET OF THE THOMPSON INDIANS (AFTER BOAS).

It occurs especially on ancient seals and pottery. Dolphins were popular on bas-reliefs. A silver bowl from Solgoi, decorated with an incised fish, is worthy of special mention.

The fish was commonly used in the art of Russia and Siberia. This is especially true of earthenware from Ukraine. It is also found in the paper patterns of the Amur tribes.

The motif occurs frequently in the art of China and Japan and usually in realistic form. It is found on numerous netsukes, inros, tsubas, pottery and screens. The carp, known as the yu, is the species most often figured. This was chosen as the symbol of vigor, endurance, perseverance and power because to reach the headwaters of the stream to spawn, it had to leap the cataracts and falls. A beautiful painting, "Carp ascending a stream," has been executed by Kersai. The taid, a species of bream, is also used considerably in Japanese art. It is the attribute of Ebisii, one of the seven gods of happiness. Sesshō has immortalized this god in an excellent painting, "Ebisii the Fisherman." Paintings of the fish have been found as early as A.D. 618, but the finest work belongs to later generations.

An ancient Chinese cup of the Ming dynasty is decorated with two fish and a floral pattern. This bears the mark of the Chia Ching period, about 1522–66 B.C. Another ancient work of art is a goblet-shaped cup of white porcelain, with three fishes in red, under the glaze. This beautiful piece is figured in color by Hobson, "Chinese art." It belongs to the Ming dynasty and bears the mark of the Hsuan Te period, about 1426–35 B.C.

The legend of Gyoran Kwannona, daughter of King Miao To Houang, had its influence on Japanese art. She lived about 2577 B.C. and entered a monastery where she was finally directed by Buddha to retire to the island of Puto.

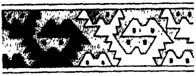
There she remained for nine years and established many monasteries. She is frequently figured carrying baskets of fish, a sort of saint.

The fish motif does not occur in Greek art until a later date. Among a collection of Mycenaean painted pottery there is a cup, decorated with fish and swans, which dates about 900–600 B.C. Other vessels show the octopus motif.

Old Greek coins were frequently inscribed with fish. Dolphins were used commonly during the third and fourth centuries preceding the birth of Christ, but the fish appears to be less common. A coin from Agrigentum dated 431–437 B.C. bears on the reverse a sea perch, a crab and a shell. The crab was the badge of Agrigentum and held a prominent place as the coin type of the city. This coin was used for a period of six or seven years just preceding the capture of Agrigentum by the Carthaginians in 400 B.C. The obverse of this coin bears an eagle tearing a hare that lies on the seashore. A coin from Cyzicus, dated 700–400 B.C., is inscribed with a tunny fish with fillets on each side. A silver coin from Gades, under Roman rule, has a head on the obverse and a fish on the reverse.

The fish is a familiar figure on old maps and has been used by astronomers for centuries. Aratus, 315–245 B.C., enumerates forty-four constellations, and among them is Pisces. Pisces fills the twelfth sign of the zodiac and is represented by two fishes tied together by their tails. In the Greek legend, Aphrodite and Eros, while on the banks of the Euphrates, were surprised by Typhon and sought safety by jumping into the water, where they were changed into two fishes. This is probably an adoption of an earlier Egyptian tale.

The fish was an early symbol of Christ in primitive and medieval art. The origin is to be found in the initial letters of the names of the titles of Jesus in Greek; Jesus Christ, Son of God, and Saviour,

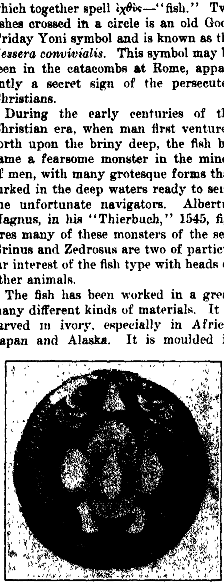


INTERLOCKED FISH PATTERN FROM PERUVIAN FABRIC (AFTER CRAWFORD).

which together spell ἰχθὺς—"fish." Two fishes crossed in a circle is an old Good Friday Yoni symbol and is known as the *Tessera convivialis*. This symbol may be seen in the catacombs at Rome, apparently a secret sign of the persecuted Christians.

During the early centuries of the Christian era, when man first ventured forth upon the briny deep, the fish became a fearsome monster in the minds of men, with many grotesque forms that lurked in the deep waters ready to seize the unfortunate navigators. Albertus Magnus, in his "Thierbuch," 1545, figures many of these monsters of the sea. Erinus and Zedrosus are two of particular interest of the fish type with heads of other animals.

The fish has been worked in a great many different kinds of materials. It is carved in ivory, especially in Africa, Japan and Alaska. It is moulded in



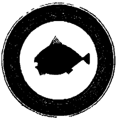
JAPANESE TSUBA OF OTSUKI SCHOOL (AFTER GUNSAULUS).

copper, iron, gold and even in lead. A hanging lead cistern of the seventeenth century, England, is decorated with a dolphin. The fish is frequently used as a mark on porcelain and pottery from Germany, China, Switzerland, Venice, Holland and probably elsewhere The printer's mark of the Aldi of Venice is an anchor with a fish twined about and bearing the letters A. L

The fish also assumes a prominent part in heraldry and totemism, a discussion which we can not enter here

It plays an important part in the art of the American Indian. In the Northwest, it is carved in wood and is frequently seen on totem poles. The sculpin swallowing a fish is a common motif of the Kwakiutl In British Columbia, it occurs chiefly as a design on baskets The spear, fish-hook, fish-net and fish backbone are the motifs most often represented. It was used on the codices in Mayan art The word fish "cay" is the sign used on the original element in the Katun glyph which expressed the concept 20. In Guiana, the fish is generally found on baskets. The Merokot is represented by a highly conventionalized pattern. In Brazil, the fish is represented by a triangle. Sometimes fish scales are indicated by hexagonal figures The fish reaches its perfection in the conventionalized art of Peru It is a common motif on fabrics and invariably the pattern consists of two fishes, turned in opposite directions, making the "interlocked fish design" It is also incised on pottery or moulded into the form of a fish. The octopus is likewise a common design in Peru

The simple form of the fish and its universal abundance throughout the world has contributed largely to the general use of this motif in art The material for study is unlimited, and the present article does not pretend to exhaust the subject. It may serve to guide some one who cares to pursue the motif more intensely



MOTIF FROM MIMBRES POTTERY
(AFTER COSGROVE). MANY OTHER BEAUTIFUL FISH PATTERNS HAVE BEEN FOUND ON POTTERY FROM THE SWARTZ RUINS.

THE PROGRESS OF SCIENCE

IN MEMORIAM: WILLIAM HENRY WELCH (1850–1934)

THE death of Dr. Welch, on April 30, leaves a distinct void, not only in the American medical profession, of which he was easily the topmost figure; but, particularly in those wide fields of public hygiene and social welfare to which he devoted most of his later life. His passing, after a year's illness in the Johns Hopkins Hospital, was peaceful, unconscious, hence a fitting close to a life so wonderfully variegated, of such substantial accomplishment and such exclusive devotion to altruistic aims. In capacity for sheer enjoyment of existence, he was like unto the English physician of whom Dr. Johnson observed. "Dr. Mead lived more in the broad sunshine of life than any man." In the serene, cheerful, stoical fortitude with which he weathered the pains and tediums of his last illness, Dr Welch was like the well-disciplined soldier, the least of whose virtues is "never to complain."

Coming of a long line of New England physicians, imbued from boyhood up with the essential atmosphere of medicine, it was but natural that Welch should follow the colonial tradition by fitting himself for the family profession at Columbia after his graduation from Yale (1870). Three years of postgraduate work in Europe under such masters as Carl Ludwig and Cohnheim, memorable contacts with such rising stars as Koch and Ehrlich, gave him a broad foundation in scientific medicine, such as few, if any, Americans of equal enterprise had acquired in his time. Back in New York, he supported himself by coaching medical students, later by medical practise, in connection with his chair of pathology in Bellevue Hospital Medical College (1879–84), where he established our first pathological laboratory. But his real future had already been decided. Billings, who planned the Johns Hopkins Hospital, and Cohnheim had already recommended Welch for the prospective Baltimore chair, whence his appointment to the Baxley professorship of pathology (1884) became a foregone conclusion. Before settling in the new environment, Welch spent another year of intensive laboratory training in Europe and may be said to have brought the newer bacteriology (of the Koch tradition) to the United States. With the opening of the Johns Hopkins Hospital (1889), he acquired adequate laboratory facilities and had already become widely known as the outstanding teacher and investigator of his disciplines in the country. In Cohnheim's laboratory, he had already made his mark through an original investigation of pulmonary œdema (1875). Important studies on glomerulo-nephritis, thrombosis and the pathology of fever followed. In 1891, he discovered the two pathogenic bacteria with which his name is best associated, *viz.*, the *bacillus aerogenes*, now known as *bacillus Welchii*, which activates gas-gangrene in wounds, and the staphylococcus which infects the edges of wounds from the skin. The importance of the Welch bacillus came to a focus on the Western Front, where the rotary motion of the projectile in gunshot wounds created an ideal pulpy culture medium for gas infection; while the significance of the *Staphylococcus epidermidis albus* as a source of wound infection in the sterilizable field of operation had long since been recognized in the surgical clinic. In connection with Dr. Welch's distinguished military career during the world war, it was not without reason, then, that General MacArthur, the Chief of Staff, requested that his body be buried as a national figure in the National Cemetery, at Arlington, under the aegis of the Army he had served so well.

Associated with Welch in these impor-

(From a painting by Thomas C. Corner, University Club, Baltimore, Md.)
WILLIAM HENRY WELCH

tant findings were two of his most brilliant pupils, Simon Flexner, who also collaborated with him in a pioneer investigation of the toxins of diphtheria (1891), and Nuttall. With a terminal study of the many morbid conditions activated by the gas bacillus (1900), Welch's laboratory period came to an end. In his second period, he was to live forward through and by his pupils; a long and impressive list, from Gorgas, in the Bellevue period, to Councilman, Thayer, MacCallum, Whipple, Blumer, Cullen, Opie, Winternitz, Abbott, Whitridge Williams, Bloodgood, Carroll, Lazear and Walter Reed. Through the work of some of these men, Welch *"hat Schule gemacht."* Their devotion to the master was that of a group of loyal regimental adjutants to their commanding officer

Welch's association with Osler, Halsted and Kelly in the development of the Johns Hopkins Medical School is commemorated in the Sargent painting. Osler brought in the great English tradition of bedside medicine; Welch and Halsted the Germanic program of laboratory and university clinic; Kelly the skill and enterprise of the self-helping surgeon of the pioneer American tradition, with a trace of the physician-naturalist, of the type of Conrad Gesner, Linnaeus or Johannes Müller. The teamwork of these four men and their pupil-associates made the Johns Hopkins the most efficient and productive medical school in the country. When Welch came to Baltimore, one of his Bellevue associates observed: "You may become a connoisseur of terrapin and madeira, but as a pathologist—good-bye!" As he approached his third period, that of activation and national leadership in medicine and international hygiene, Welch had long been in request everywhere as the engaging diner-out, the witty *raconteur*, the experienced presiding officer at medical meetings and other state occasions. As a prime-mover of American medicine, he was the natural, lineal successor of Billings, Weir Mitchell and Jacobi, whose leadership had been tacitly recognized, in turn, and never disputed. Welch's leadership became national and international at the outbreak of the world war and in connection with his services to the government. But for this interruption, his presidency of the National Academy of Sciences (1913–16) might have been made "perpetual," had he chosen, as with Fontenelle and Flourens in France. Welch's services to medical education in China and similar contacts in Europe made him more and more of an international figure. Upon his retirement from his chair of pathology (1916) came the School of Hygiene and Public Health, which he directed for a decade (1916–26); followed by two sabbatical years in Europe, spent in collecting books for the Welch Medical Library, then building. Here he found himself in harness again as professor of the history of medicine and director of the Institute, in which his successor, Professor Sigerist, has made such a brilliant record. Thus Welch was leader, prime-mover and activator to the last Always an omnivorous reader, his declining years, as in Osler's case, were devoted to the love of books.

As he approached the scriptural span, Dr. Welch began to age perceptibly; but once he got his second wind, he grew younger with each succeeding year. Old friends, who heard his charming Californian reminiscences in 1930, declared him younger than ever before. Endowed with phenomenal vitality or strength of mind and body, extraordinary breadth of vision and a singular tenacity of memory and opinion, his nature was genial, lovable, attractive, receptive and hospitable to a fault. In any group-photograph of scientific men, his short, sturdy, thickset figure stands out, like some survival or evocation of a great past. His life of 84 years was rich and varied. In succession, we find him teaching Greek and Latin for a living

at Norwich, intimate and fellow student of the coming leaders of German medicine; the favorite physician of actors, actresses and detectives in New York City; the leading citizen of Baltimore and Maryland; a prominent adviser of the Rockefeller, Carnegie and Milbank Foundations; a major, colonel and brigadier general in the Army; eating through innumerable course dinners which would have killed any other man of his physical conformation, hoaxing Osler; being photographed with Mary Pickford; crashing through breakers at Atlantic City; laughing uproariously at the burlesque of himself in the students' "Pithotomy"; spending the night in Turkish bath establishments to hide away from importunate visitors; a maker *in posse* of scientific medicine in China and recipient of the most unique birthday honors ever accorded. His eightieth birthday was simultaneously celebrated in all the larger scientific centers of the world; yet he modestly waived the distinction as belonging properly to the profession he represented.

The likeness of Dr. Welch here reproduced, from the oil-painting by Thomas C. Corner (University Club, Baltimore), shows him in his prime and at his best. Here we have the massive head and brow of the essential high priest of knowledge; the huge, ventripotent frame of the epicure and lavish dispenser of hospitality; the keen, withal benevolent gaze of the intimate adviser of great financier-philanthropists. The three stages of Dr Welch's life, the period, just ended, of unstinted endowment of scientific research, are all epitomized in this portrait. As Senator Walcott has intimated, Dr. Welch was a kind of Buddha, consecrated exclusively to the intellectual life and to altruistic pursuits; yet one to whom nothing human was alien But about him there was nothing of the *vieux bonze*, the self-appointed bishop *in partibus*. His sly twinkle, his omnipresent elfin humor precluded any assumption of self-reference. Like the Priest of Nemi, in Renan's drama, he was one of those advanced liberals, who seemed, at whiles, to sell out his fellow countrymen through exaggerated esteem for foreign culture and thinking too far in advance of his time. If he was sometimes beguiled by self-seeking parasites, to the detriment, sometimes the disgust of his faithful coadjutors, it was but an obvious defect of his great qualities The rest is a simple case of Newton's Third Law of Motion. Unless the civilized world relapses into barbarism, such steadfast devotion to altruistic aims, such broad-visioned love of his fellow men, can not fail of lasting recognition in the end. Fifty years ago, Dr. Welch affirmed that not sanitation but "nothing short of a social revolution" will alleviate the misery of the poor and unfortunate. Some such revolution is now in process all over the world. In some happier, less chaotic period than ours, Welch will come into his assured position as one of our greatest national figures and benefactors, *pia anima in pace*.

F. H. GARRISON

THE SEVENTY-FIRST ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE National Academy of Sciences held its seventy-first annual meeting on April 23, 24 and 25 at the academy building in Washington, D. C. At this season of the year Washington is especially beautiful; the Japanese cherry trees are in full bloom, the shrubs in blossom, and the trees in nearly full leaf. This feature, together with the fact that several other scientific societies hold meetings directly after the academy sessions, makes Washington attractive to scientists and assures good attendance at the meetings, even though hotel accommodations may be difficult to secure.

The papers on the scientific program

DR. NORBERT WIENER
PROFESSOR OF MATHEMATICS
THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROFESSOR HARRY S. VANDIVER
ASSOCIATE PROFESSOR OF MATHEMATICS
THE UNIVERSITY OF TEXAS

numbered 55 and covered a wide range of subjects. Their distribution among the fields of science was the following. Mathematics 1; astronomy 5; physics 13; chemistry 3; geology 8, meteorology 2; botany 7; biology 3; zoology 1; physiology 3; pathology 2, medicine 3, genetics 1; psychology 1; anthropology 1; general science 1. Forty-one papers were presented by members of the academy and thirteen by non-members. The large number of communications in physics reflects the intense activity in this field of science at the present time Sir Arthur Eddington, foreign associate of the academy, presented a paper entitled "Unification of Relativity Theory and Quantum Theory." Drs. Stebbins and Whitford described the photoelectric amplifier and its application to the photometry of faint stars and nebulae. Drs. Millikan and A. H. Compton reported on recent results obtained in the field of cosmic rays. Drs. Lauritsen and Crane described experiments on transmutations by artificially accelerated particles, the accelerations being produced by use of the high potential x-ray tube developed at the California Institute of Technology Drs A H Compton and Wollan deduced the "appearance" of atoms of helium, neon and argon, as observed by x-rays, from the image obtained by photographing a rotating template whose shape was calculated by a mathematical transformation of measured values of the x-rays scattered by the respective gases Dr H. Fletcher analyzed loudness and pitch of musical tones and their relation to intensity and frequency; Dr. C. E. Seashore approached the subject from a slightly different view-point and spoke on the quality of sound. By invitation, Dr. B. F J. Schonland exhibited photographs of lightning discharges and their development, as taken by the special camera devised by C. V. Boys. Drs Osterhout and Hill described experiments on cells of the fresh-water plant *Nitella*, in which stimuli were found to be transmitted by

DR. ERNEST O. LAWRENCE
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THE UNIVERSITY OF CALIFORNIA

DR. VANNEVAR BUSH
DEAN OF THE ENGINEERING SCHOOL
THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

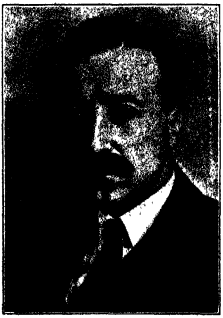
DR. DENNIS ROBT. HOAGLAND
PROFESSOR OF CHEMISTRY
THE UNIVERSITY OF CALIFORNIA

DR. JAMES F. NORRIS
PROFESSOR OF ORGANIC CHEMISTRY AND DIRECTOR OF THE RESEARCH LABORATORY
THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

negative variations which travel along the cell, just as in muscle and nerve. Sufficient exposure of *Nitella* cells to distilled water abolishes the characteristic variations when stimulated by an electric current. The simplest explanation is that an organic substance is dissolved out of the surface by distilled water. It seems possible that other cases of anesthesia may be due to the fact that substances are removed from the cell. Dr. Earl H. Myers exhibited an interesting motion picture showing the life history of the foraminifer *Patellina corrugata*.

DR. CHARLES PALACHE
PROFESSOR OF MINERALOGY
HARVARD UNIVERSITY

Drs. Henderson, Oughterson, Greenberg and Searle reported on muscle tonus, itself controlled from the central nervous system and considerably influenced by the respiratory center, as the basic factor determining the amount of metabolism and the correlated volumes of the circulation and respiration and as an element of prime importance in the venopressor mechanism. Experiments described by Dr. Simon Flexner showed clearly that the source and mode of infection in poliomyelitis is through the nasal passages and that the virus is confined to the human host and passes from individual to individual in the secretions of the nose and throat. Dr. Douglas Johnson concluded from physiographic evidence that the supposed meteorite scars of South Carolina represent former lake basins surrounded by rims of wind-blown sand, rather than meteor impact forms. Dr. J. C. Merriam emphasized, in a paper on "Science and Conservation," the responsibility which science



DR. JOHN H NORTHROP
MEMBER, THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

has for making clear the present and future significance of materials needed for scientific investigation, for intellectual appreciation and for economic use.

On Monday evening Dr. Edwin Hubble delivered the evening lecture and presented a most interesting statement on the "Realm of the Nebulae." The attendance at the lecture was 510.

The average attendance at the sessions in the Auditorium was 450 and in the

DR. HERBERT S. GASSER
PROFESSOR OF PHYSIOLOGY
CORNELL UNIVERSITY MEDICAL COLLEGE

DR. E. NEWTON HARVEY
PROFESSOR OF PHYSIOLOGY
PRINCETON UNIVERSITY

Lecture Room, 160. One hundred and twenty-seven academy members and two foreign associates registered at the meeting. At the annual dinner on Tuesday evening President Campbell delivered, at the request of the local committee, a brief address on the status of academy activities at the present time. This was followed by the presentation of five medals:

Agassiz Medal. Awarded to Bjorn Helland-Hansen, of the Geofysiske Institut, Bergen, Norway, in recognition of his work in physical

DR. SEWALL WRIGHT
PROFESSOR OF ZOOLOGY
THE UNIVERSITY OF CHICAGO

oceanography, especially for his contributions to knowledge of the dynamic circulation of the ocean. The presentation address was made by Dr. H. B Bigelow. In the absence of Dr. Helland-Hansen the medal was received for him by The Honorable Halvard H. Bachke, Minister from Norway.

Elliot Medal and Honorarium of $200 for 1930. Awarded to George Ellett Coghill, Wistar Institute of Anatomy and Biology, Philadelphia, Pennsylvania, in recognition of his work: "Correlated Anatomical and Physiological Studies of the Growth of the Nervous System in Amphibia." The presentation address was made by Dr. Ross G. Harrison.

Elliot Medal and Honorarium of $200 for 1931. Awarded to Davidson Black (since deceased) Dr. Black, a native of Canada, was professor of anatomy at the Peiping Union Medical College, Peking, China, at the time of his death on March 15, 1934. The award was made in recognition of his work on an adolescent skull of *Sinanthropus Pekinensis* in comparison with an adult skull of the same species and with other hominid skulls, recent and fossil The presentation address was made by Dr. Henry Fairfield Osborn. The medal was received by Dr. Frank Dawson Adams, foreign associate of the academy, from Canada, on behalf of the legal representative of Dr. Black

DR. THOMAS M. RIVERS

MEMBER, THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

Public Welfare Medal. Awarded to David Fairchild, formerly of the U. S. Department of Agriculture, Washington, D. C., for his exceptional accomplishments in the development and promotion of plant exploration and the introduction of new plants, shrubs and trees into the United States. The presentation address was made by Dr. Henry H. Donaldson. The medal was received by Dr. K. A. Ryerson, chief of the Bureau of Plant Industry of the U. S. Department of Agriculture on behalf of Dr. Fairchild, who was unable to be present.

Charles Doolittle Walcott Medal and Honorarium of $1,350. Awarded to David White, of the U. S. Geological Survey, Washington,

DR. ELVIN C. STAKMAN

PROFESSOR OF PLANT PATHOLOGY THE UNIVERSITY OF MINNESOTA

DR. EDWARD SAPIR

PROFESSOR OF ANTHROPOLOGY AND LINGUISTICS YALE UNIVERSITY

D. C., in recognition of his work, published and unpublished, on the Precambrian algae life of the Grand Canyon of Arizona. The presentation address was made by Dr. Charles Schuchert.

At the business meeting held on Wednesday, April 25, the following officers and members were elected:

Foreign Secretary. Dr. T. H. Morgan, of the California Institute of Technology, Pasadena, California, for a period of four years, commencing July 1, 1934.

New Members of the Council of the Academy: H. S. Jennings, of the Johns Hopkins University, Baltimore, Maryland, and Roger Adams, of the University of Illinois, Urbana, Illinois, for a term of three years, commencing July 1, 1934.

New Foreign Associates: V. F. K. Bjerknes, of the Physical Institute of the University of Oslo, Oslo, Norway, and Robert Robinson, of the University of Oxford, Oxford, England.

Fourteen men were elected to membership. Their photographs accompany this article.

The present membership of the academy is 285, with a membership limit of 300; the number of foreign associates is 45 with a limit of 50.

The autumn meeting of the academy will be held this year on November 19, 20 and 21 at Cleveland, Ohio.

F. E. Wright,
Home Secretary

THE JUNE STRATOSPHERE BALLOON FLIGHT

Plans are being formulated for a balloon ascent into the stratosphere early in June, under the joint auspices of the National Geographic Society and the United States Army Air Corps. Major William E. Kepner, an outstanding balloon pilot, and Captain Albert W. Stevens, aerial photographer, both of the United States Army Air Corps, will participate in the flight.

The ascent is being made to obtain information concerning upper regions of the atmosphere. There is no desire to perform a "stunt" or to establish an altitude record for its own sake. A large balloon will be used so that two men and a large number of scientific instruments and devices can be taken to the highest practicable altitude.

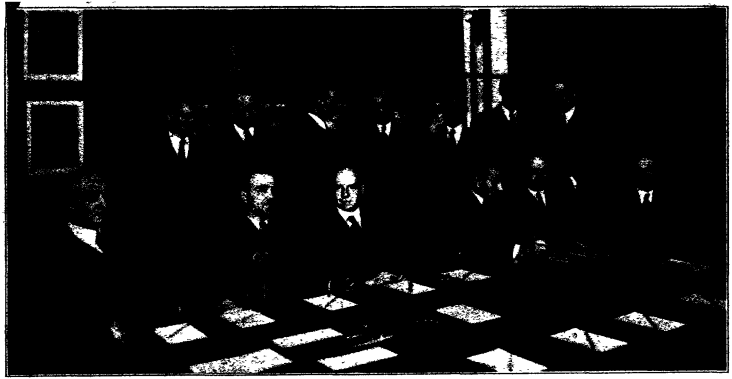
The specific projects to be carried out include:

Temperature and barometric measurements from the earth to the "ceiling" of the flight; a check on barometer measurements of altitude by optical methods; a camera of accurately determined focal length, mounted in the bottom of the gondola, to photograph the earth, making it possible through subsequent map studies to compile more accurate altitude tables than those now in use; bottling of air samples at various altitudes, samples being brought to earth and analyzed for gas composition and relative humidity, ascertainment of electrical condition of the atmosphere from the 5,000-foot level to the flight "ceiling"; recording cosmic ray intensity, penetration and direction of movement, at various levels, wind direction and velocity studies; measurement of solar radiation; photography of the solar spectrum; record of sky brightness;; oblique photography for distance, and test of actinic value of light, and secondary absorption by the atmosphere; effects of altitude on radio transmission; balloon navigation problems, particularly effects of "superheat" acquired by balloon and gondola.

Other projects may be added if the time of the observers permits and if satisfactory methods can be worked out. Efforts are being made, for example, to devise satisfactory plans and equipment to ascertain the presence of ozone at high levels. The ozone in the upper air can not be determined from the air samples brought to earth, as the gas is unstable and will break down into ordinary oxygen.

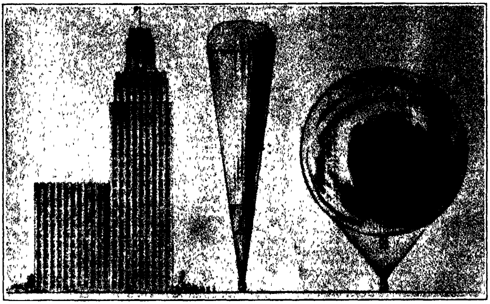
Construction of the balloon is now well under way in the factory of the Goodyear-Zeppelin Corporation, Akron, Ohio. It is five times the size of the balloon used by Commander Settle and Major Fordney in November, 1933, and three and a half times the size of the Russian balloon which rose into the stratosphere in September, 1933.

Two and one third acres of cotton cloth are being used to build the bag and it will contain, fully inflated, 3,000,000 cubic feet of gas. It will be about one thirteenth filled with hydro-



THE MEETING OF THE ADVISORY COMMITTEE OF SCIENTIFIC MEN

WHO ARE DIRECTING ARRANGEMENTS FOR THE STRATOSPHERE FLIGHT, HELD IN THE BOARD ROOM OF THE NATIONAL GEOGRAPHIC SOCIETY MEMBERS FROM LEFT TO RIGHT ARE: (SEATED) DR. FREDERICK V. COVILLE, U. S. DEPARTMENT OF AGRICULTURE, MAJOR WILLIAM E KEPNER, U. S. ARMY AIR CORPS; DR. LYMAN J. BRIGGS, *chairman*, DIRECTOR, U S. BUREAU OF STANDARDS; CAPTAIN ALBERT W STEVENS, U. S ARMY AIR CORPS, DR. GILBERT H. GROSVENOR, PRESIDENT, NATIONAL GEOGRAPHIC SOCIETY, AND DR. CHARLES F MARVIN, FORMERLY CHIEF, U. S. WEATHER BUREAU, (STANDING) DR. W. G. BROMBACHER, MR. E R WEAVER AND DR F L. MOHLER, OF THE U S BUREAU OF STANDARDS; MR GEORGE W. HUTCHISON, SECRETARY, NATIONAL GEOGRAPHIC SOCIETY; CAPTAIN RAYMOND S PATTON, DIRECTOR, U S COAST AND GEODETIC SURVEY; DR. FLOYD K. RICHTMYER, DEAN, GRADUATE SCHOOL, CORNELL UNIVERSITY, NATIONAL ACADEMY OF SCIENCES. DR. W. F. G. SWANN, DIRECTOR, BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE, SWARTHMORE, PA.



THE SIZE OF THE BALLOON

WHEN READY TO LEAVE THE GROUND THE BALLOON WILL HAVE THE SHAPE SHOWN IN THE CENTRAL FIGURE. IT WILL BE LESS THAN ONE TENTH FILLED WITH HYDROGEN, AS SPACE MUST BE LEFT FOR EXPANSION OF THE GAS IN THE UPPER AIR. WHEN THE BALLOON IS READY TO RISE, ITS TOP WILL BE 295 FEET ABOVE THE EARTH—HIGHER THAN THE 26-STORY OFFICE BUILDING SHOWN AT THE LEFT. AT THE TOP OF ITS FLIGHT (NEARLY 15 MILES ABOVE SEA LEVEL) THE BALLOON WILL HAVE EXPANDED TO BECOME A SPHERE 180 FEET ACROSS. THE FIGURE AT THE RIGHT INDICATES THAT THE HUGE BALL WOULD THEN BE LARGE ENOUGH TO ENCLOSE AN 11-STORY CUBICAL BUILDING

gen when it leaves the ground. Room must be left for great expansion of the hydrogen in the upper air where pressure is light.

The gondola will be an airtight hollow ball of Dow metal, a light magnesium alloy, 8 feet, 4 inches (100 inches) in diameter. The shell of the globe will be slightly less than one fifth of an inch thick. Inside, vertical tubular posts will strengthen the shell and maintain the globular shape against the strains created by the suspension and the heavy load of instruments and ballast. In the lower part of the gondola a floor of metal 60 inches in diameter will be constructed for the convenience of the two operators.

The flight will take place near dawn, as early in June as weather conditions will permit. Complete weather information will be furnished by the U. S. Weather Bureau, and the flight will be undertaken only when there is probability of slow air movement at the surface of the earth, and freedom from clouds and haze between the earth and the stratosphere.

The point of take-off will be somewhere in the western United States near the eastern edge of the Rocky Mountains. It is estimated that the balloon will drift about 600 miles to the east, southeast or northeast before dusk. With the take-off near the Rockies the landing should be made in the open country, permitting salvage of the bag.

If the flight in June is successful and the bag can be salvaged in good condition, a second flight will probably be made in September with the same personnel from the same locality, in order to check observations under similar conditions.

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